JOURNAL
OF THE
FISHERIES RESEARCH BOARD
OF CANADA

Volume 24, No. 12

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OTTAWA
DECEMBER
1967

Editor:

J. C. Stevenson

Associate Editor: G. I. Patterson
Assistant Editor: R. H. Wiswell

Production: R. L. MacIntyre

Fisheries Research Board of Canada
Office of the Editor
116 Lisgar Street
Ottawa 4, Ont., Canada

Manuscripts for publication should be addressed to the Editor

Cuvier's Beaked Whale (*Ziphius cavirostris*) Stranded in Northern California[1]

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ABSTRACT

Four Cuvier's whale strandings in northern California within 26 minutes of latitude include two of known date (March and September) and three of known sex and inferred maturity (adult male, juvenile male, large and presumably adult female). The large male and female showed a variety of external white markings, including oval white marks and mottled white marks, and the male also had scratch-like marks on its back. Oval white marks were concentrated in the urogenital region. Based upon cranial features the large male and female were presumably adult, although indirect evidence indicates that absolute length is no good criterion of maturity in *Ziphius cavirostris*. Study of the juvenile skull indicates that with increasing age in this species the orbitosphenoid bone projects progressively farther out of the optic foramen, and the mandibular symphysis fuses.

INTRODUCTION

The Cuvier beaked whale, *Ziphius cavirostris*, is a ziphiid or beaked whale of wide distribution (Moore, 1963a) that is seldom found stranded on the California coast. The biology of this species is poorly known, for few fresh animals find their way into the hands of a biologist. Many of the specimens upon which knowledge is based were found stranded on the beach. Cuvier's beaked whale is sometimes taken commercially in waters off Japan, but as yet no comprehensive study has been published. Daugherty (1965) has briefly summarized some California records. The records that have accrued for the northern California coast include four specimens for which there are data on both external morphology and osteology; this report describes these four records in detail.

STRANDING RECORDS

On the morning of March 2, 1957, an adult male *Ziphius cavirostris* was observed and photographed by W. J. Houck at the mouth of the Mad River, Humboldt County, near Arcata, California (lat 40°56′N, long 124°08′W). Attention was first directed to the animal by a local morning newspaper article, misidentifying it as a gray whale. The carcass (HSC 57-1) was in excellent

[1]Received for publication May 3, 1967.

J. Fish. Res. Bd. Canada, 24(12), 1967.
Printed in Canada.

condition, indicating that death had been quite recent. There were no food remains in the stomach. Photographs and a color description of this specimen have been published (Houck, 1958), and we here present measurements (Tables II, III) and photographs of the skull, mandibles, and intact animal (Fig. 1, 3, 5).

On November 24, 1957, Houck investigated a report of a small whale stranded on Big Lagoon Beach, Humboldt County, California (lat 41°10′N, long 124°07′W). The animal proved to be a juvenile male *Ziphius cavirostris* (HSC 57-2) very poorly preserved. The carcass was blackened and badly abraded, hence the original color pattern was not evident. Measurements (Table I) were taken and the skull and mandible (Fig. 2, 5 and Tables II, III) were saved.

On September 22, 1959, Houck received a report of a recently dead whale on the beach at Gold Bluff, Prairie Creek State Park, Humboldt County, near Orick, California (lat 41°22′N, long 124°05′W). According to a park employee the whale *Ziphius cavirostris* had stranded there the day before. The whale (HSC 59-3), a large female, was entirely dark slate grey except for the anterior end, where the throat and lower jaw were white except for some grey extending from the flanks through the eye to the throat groove on each side. The light grey on the anterior portion of the head (Fig. 3) extended to behind the blowhole, where it blended with the darker grey of the back and flanks. Omura et al. (1955, pl. 10) figured a female taken far off the west coast of Japan that is similar in coloration except for the apparent lack of the round scars and parallel scratches which were very numerous on the adult male from Mad River (HSC 57-1; Houck, 1958). These scars and scratches were nearly absent on the female specimen. Teeth did not show externally, but when the skull was prepared a single pair was found at the tip of the lower jaw. We are indebted to Dale Rice and Clifford Fiscus for determining that one of these teeth contained eight laminations (Clifford Fiscus, personal communication). The stomach contained more than 1 liter of squid beaks. The skull and mandibles (Fig. 4, 5 and Tables II, III), an innominate bone 130 mm in length, and part of the hyoid apparatus were saved.

On February 17, 1963, state park personnel reported to Houck that a whale was stranded on the beach at Freshwater Lagoon near Orick, Humboldt County, California (lat 41°16′N, long 124°06′W). Upon investigation the whale proved to be a large *Ziphius cavirostris*, represented by a blackened, abraded, and partly buried carcass (HSC 63-1). It was too badly decomposed to determine the sex by checking gonads or by the nature of the genital aperture. The fact that teeth were not visible until the lower jaw was prepared might suggest that the animal was a female. Clifford Fiscus and Dale Rice determined that there were 32 ± laminations in one of these teeth, 23 dentinal layers and 9 in the cementum beyond and after the dentine closed (Clifford Fiscus, personal communication). External measurements were taken (Table I) and the mandibles (Fig. 5 and Table III) and one pelvic bone 113 mm in length were saved.

TABLE I. External measurements, parallel to body axis, of *Ziphius cavirostris* carcasses washed ashore in northern California. Measurements, numbered as by Norris (1961), are in centimeters; proportions, in parentheses, are expressed in thousandths of total length.

Measurements	HSC 57-1	HSC 57-2	HSC 59-3	HSC 63-1
1. Total length, tip of upper jaw to fluke notch	599 (1.000)	320 (1.000)	622 (1.000)	650 (1.000)
2. Length from tip of upper jaw to center of eye	– –	38 (.119)	61 (.098)	66 (.102)
3. Length from tip of upper jaw to apex of melon	– –	– –	– –	11 (.017)
4. Length from tip of upper jaw to angle of gape	– –	30 (.094)	– –	31 (.048)
5. Length from tip of upper jaw to ear	– –	– –	– –	66 (.102)
9. Length from tip of upper jaw to center of blowhole	– –	38 (.119)	64 (.103)	– –
10. Length from tip of upper jaw to anterior origin of flipper	– –	81 (.253)	– –	130 (.200)
11. Length from tip of upper jaw to tip of dorsal fin	– –	216 (.675)	– –	– –
13. Length from tip of upper jaw to midpoint of genital slit	– –	200 (.625)	399 (.642)	– –
14. Length from tip of upper jaw to center of anus	– –	214 (.669)	429 (.658)	– –
21. Girth	– –	– –	– –	336 (.517)
29. Length of flipper from anterior origin to tip	– –	33 (.103)	48 (.077)	69 (.106)
30. Length of flipper from axilla to tip	– –	– –	– –	46 (.071)
31. Width of flipper	– –	11 (.034)	19 (.031)	18 (.028)
32. Height of dorsal fin from fin tip to base	– –	17 (.053)	– –	25 (.039)
33. Length of dorsal fin base	– –	23 (.072)	42 (.068)	49 (.075)
34. Width of flukes from tip to tip	– –	86 (.269)	168 (.270)	203 (.312)

TABLE II. Measurements of skulls from *Ziphius cavirostris* carcasses washed ashore in northern California. All figures are in millimeters; approximations are in parentheses. Numbers are those used by Moore, 1963b.

Measurements	HSC 57-1	HSC 57-2	HSC 59-3
1. Total length	907	515 +	923
2. Greatest length of rostrum	485	270 +	520
3. Tip of rostrum to posterior margin of pterygoid nearest midsagittal plane	690	268 +	688
4. Tip of rostrum to most posterior wing of pterygoid	738	394 +	–
5. Tip of rostrum to most anterior extension of pterygoid	431	238 +	420
6. Tip of rostrum to most posterior extension of maxillaries between palatines on the palate	466	230 +	470
7. Tip of rostrum to most posterior extension of maxillary plate	752	420 +	797
8. Tip of rostrum to anterior margin of superior nares	(696)	378 +	(708)
9. Tip of rostrum to most anterior point on premaxillary crest (i.e. to anterior tip of nasals)	591	–	635
10. Tip of rostrum to most posterior extension of temporal fossa	792	446 +	808
11. Tip of rostrum to most posterior extension of lateral tip of left premaxillary crest	(733)	393 +	747
12. Tip of rostrum to most anterior extension of pterygoid sinus	478	245 +	468
13. Greatest length of temporal fossa	138	78	147
14. Greatest length of orbit	128	86	128
15. Greatest length of right nasal bone on vertex of skull	145	70	115
16. Length of nasal suture	127	(64)	100
17. Greatest breadth of skull across postorbital processes of frontals	559	279	553
18. Greatest breadth of skull across zygomatic processes of squamosals	542	284	536
19. Greatest breadth of skull across centers of orbits	532	261	544
20. Least breadth of skull across posterior margins of temporal fossae	345	215	317
21. Greatest breadth of occipital condyles	167	96	162
22. Greatest width of an occipital condyle	59	34	62
23. Greatest length of an occipital condyle	112	76	111
24. Greatest breadth of foramen magnum	58	41	57
26. Greatest breadth of nasal bones on vertex	(73)	–	70
27. Least distance between premaxillary crests	(58)	35	53
29. Greatest span of premaxillary crests	236	118	200
30. Least transverse width of premaxillae where they narrow abreast of superior nares	–	(107)	(194)
31. Greatest width of premaxillae anterior to place of preceding measurement	–	(107)	(198)
32. Width of premaxillae at midlength of rostrum	(76)	(34)	(50)
33. Width of rostrum in apices of antorbital notches	332	177	323
34. Width of rostrum in apices of prominential notches	267	(126)	246

(*Continued*)

TABLE II. Measurements of skulls from *Ziphius cavirostris* carcasses washed ashore in northern California. All figures are in millimeters; approximations are in parentheses. Numbers are those used by Moore, 1963b. — *Concluded*

Measurements	HSC 57-1	HSC 57-2	HSC 59-3
35. Greatest width of rostrum at midlength of rostrum	110	(70)	98
36. Greatest depth of rostrum at midlength of rostrum	132	(36)	78
37. Greatest transverse width of superior nares	(100)	(47)	(71)
38. Greatest internal width of inferior nares at apices of pterygoid notches on the pterygoids	131	63	131
39. Height of skull, vertex to most ventral point on pterygoids	483	261	(448)
40. Greatest width of temporal fossa at right angle to greatest length	85	43	89
41. Least distance between main or anterior maxillary foramina	150	77	138
42. Least distance between premaxillary foramina	(80)	(26)	56
43. Distance from posterior margin of left maxillary foramen to most anterior extension of left maxillary prominence	(171)	(80)	(165)
44. Greatest length of vomer visible at surface of palate anteriorly	238	(155)	215
Greatest length of auditory bulla – *left*	–	52	52
Greatest length of auditory bulla – *right*	–	56	55

These four strandings occurring in Northern California involved both large individuals and a juvenile, of both sexes, but we do not consider them sufficient evidence upon which to base any conclusions regarding seasonality or distribution, since only two of the animals were known to have stranded soon after death (the March and September individuals). More significant is the fact that all stranded within 26 minutes of latitude.

DESCRIPTION OF SKULLS

Only features that differ from skull to skull, that Mitchell found pertinent in a survey of numerous other skulls of the same species, are emphasized in this description. Kernan (1918) has excellently described the entire skull of *Ziphius cavirostris* in detail.

The two larger individuals of known sex are herein presumed to be adults, an assumption based upon their skulls. The supraoccipital shields of the two adults (HSC 57-1 male and 59-3 female) bear a well-developed median ridge running from the foramen magnum up the shield about halfway, but this ridge is not at all developed on the skull of the juvenile (HSC 57-2). The female skull (HSC 59-3) shows a vertical median sulcus running dorsally from the end of the median ridge. The apex of the triangular-shaped occipital shield is relatively more pointed in the female and the juvenile, but is rounded in

TABLE III. Measurements of jaws and teeth from *Ziphius cavirostris* carcasses washed ashore in northern California. All figures are in millimeters and approximations are in parentheses.

Measurements	HSC 57-1	HSC 57-2	HSC 59-3	HSC 63-1
Greatest length of right dentary bone	810	452	799	814
Greatest length of right dentary to posterior end of symphysis	176	69	170	197
Greatest length of right dentary to posterior border of mental foramen	194	70	188	173
Greatest length of right dentary to anteromedial margin of mandibular vacuity	436	228	422	485
Height at coronoid process	168	(94)	166	148
Breadth of symphysis at posterior margin of mandibular alveoli	67	(39)	52	51
Breadth of jaws across mandibular condyles	489	–	498	–
Total length of tooth – *left*	–	–	53.0	67.5
Total length of tooth – *right*	–	–	51.5	65.5
Greatest diameter of tooth – *left*	–	–	13.7	20.5
Greatest diameter of tooth – *right*	–	–	13.8	19.2
Diameter at right angle to greatest diameter – *left*	–	–	11.5	15.0
Diameter at right angle to greatest diameter – *right*	–	–	12.0	15.2

the male. The occipital condyles of the juvenile and the male are not set off from the occipital shield by as deep a sulcus as that found in the female. The condylar surfaces in the two adult skulls are not pitted as in the juvenile, in which the pits are not shallow depressions but actually small foramina running directly into the surface of the bone for a few millimeters. The texture of the remainder of the occipital shield in the juvenile is relatively uniform, but there are numerous large nutrient foramina concentrated in an area just above the foramen magnum, and this is true to a lesser degree in the two adult skulls. The juvenile skull bears a pair of large fontanelles dorsolateral to the foramen magnum, the smallest on the left being 12 × 23 mm in size, with a supraoccipital–exoccipital suture running laterally from it. This suture can also be traced in both of the adult skulls.

The notch between the basioccipital crest and the paroccipital process is relatively wide and open in the juvenile, more appressed in the female, and even more appressed in the male. The ventral-most extension of the basioccipital crest appears to be relatively longer in the juvenile than in the adults.

A pit just inside the brain case, on the dorsal surface of the basioccipital just anterior to the foramen magnum, is shallow in the juvenile, deeper in the female, and deepest in the male.

In ventral view a median protuberance on the basioccipital is progressively more accentuated from juvenile through female to male. The posterior

border of the vomer is incised with a W-shaped notch in the juvenile, is raggedly irregular in the female although slightly W-shaped, and has irregularly squared margins in the male.

The median vertical choanal septum formed by the vomer is relatively wider in the juvenile than in the adults and does not carry a large nutrient foramen on its right ventral margin as in the adults. The pterygoid fossae of the juvenile male and the adult male do not have vertical struts developed on the ventral border of the pterygoid bones as does the female skull, which has two pairs of struts.

The female skull is atypical in showing patches of deeper bone through irregular openings in the pterygoid bone on both sides at the posterodorsal surface of the pterygoid fossa.

The ventral surface of the lacrimal bone of the juvenile bears a small foramen lateral to the antorbital foramen. This small foramen (at the lateral end of a canal that runs back into the posterior portion of the antorbital foramen) has been closed over by anterior and posterior lips of the lacrimal bone. The resulting suture runs medially from the small foramen. In both adults the foramen and suture are present on each lacrimal, but are much less obvious. In the juvenile the lacrimal bone broadly contacts the maxillary bone on both right and left sides, whereas in both adult skulls the maxillary just barely contacts the lacrimal with a slender posteriorly directed process.

The jugal bones of the juvenile male barely project anteriorly enough to enter the margin of the broadly curved "maxillary notch" (equals internal and external antorbital notches), but do send a process posterolaterally toward the preorbital process of the frontal bone. In the two adults the jugal decidedly projects into the notch, dividing it into an internal antorbital notch and an external antorbital notch, both of which are posterior to the prominential notch. The adult male skull is like that of the juvenile in having a process on the jugal directed toward the preorbital process of the frontal, but this is not so well developed in the female skull.

The orbitosphenoid bones in the juvenile are sunken far within the optic foramen, but they project far out of the optic foramina in the two adult skulls.

On the ventromedian line between the palatines, the vomer shows for a length of about 45 mm and a width of 5 mm as a short anteroventrally directed spine in the juvenile. It is much less obviously exposed in the female (38 × 2 mm), and more obviously in the adult male (95 × 6 mm). The maxillaries fuse anterior to this proximal vomerine exposure in the two adults, but not in the juvenile in which the vomer is exposed continuously from between the pterygoids out to between the premaxillaries. In the adults, especially the female, this maxillary fusion results in a boss which projects downward in lateral view, resulting in a lateral profile of the beak that is distinctive. The ventral border of the vomer anteriorly is developed into a sharp ridge on the snout of the female, more fused in with the rostral bones of the male, and unfused but comparably widened in the juvenile male skull. The vomer, maxillary, and premaxillary exposed on the ventral surface of the beak are

unfused in the juvenile skull, more closely appressed but unfused in that of the adult female, and fused or nearly so in the adult male skull.

In dorsal and anterior views the differences between the three skulls are striking. The narial gutter of the juvenile is concave; that of the female shows a median ridge, the mesorostral ossification, 12 mm high, running from the tip of the vomer back under the ethmoid; and the adult male shows only the anterior remnant of the mesorostral ossification. A large and deep spiracular basin is developed in the male (Fig. 1*d*) and not in the other two skulls. The spiracular plate of the female has high, thick lateral margins and on the right side especially is roughened and pitted. The spiracular plate of the female and juvenile male both show a flange, notch, and groove; the groove is particularly deep in the juvenile, up to 10 mm in depth. The posterodorsal margins of the premaxillaries are directed vertically in the juvenile, anterodorsally in the adults. The posterior ends of the premaxillary foramina lie about 15 mm anterior to the prominential notch in the juvenile, 10 mm posterior in the adult female, and 10–70 mm anterior in the adult male. The anterior end of the mesethmoid ossification ends about 55 mm posterior to the prominential notches in the juvenile and 40 or more mm posterior in the female, but is unmeasurable in the male.

The maxillary prominence is very weak in the juvenile, but uniformly high and strong in the two adults. Medially adjacent to this prominence and lateral to the maxillary foramina, on the right side of the juvenile skull, is a small foramen not found on the left side. In the female there is one such foramen on the right side and two on the left, and in the adult male there are two small foramina on the right and a larger one on the left. Another large foramen dorsoposterior to the orbit on the dorsal surface of the maxillaries is roofed over medially by thin bone in the juvenile, but opens more medially in the female because of a perforated canal roof, and in the male is roofed by one anteroposterior strut on the left and two on the right (Fig. 1*d*).

There is a large foramen 6 mm in diameter on the dorsal midline between the nasal bones and a smaller foramen posteriorly in the body of the right nasal of the adult male; one large foramen 4 mm in diameter in the right nasal and one large foramen in the dorsoanterior face of the right premaxillary of the adult female; and two small foramina in the right nasal bone of the juvenile male.

The mandible of the adult male (57-1) is large, heavily built, with a fused symphysis and a well-defined alveolar groove. That of the adult female (59-3) is relatively more lightly constructed, has a well-defined alveolar groove and an unfused symphysis. The mandible from the Freshwater Lagoon individual (63-1), for which there is no skull, is intermediate between the previous two in being ruggedly built, slightly larger than in the female and about the same length as in the male, with a well-defined alveolar groove, and a fused symphysis. The mandible of the juvenile male is much smaller and has a well-defined alveolar groove and a completely unfused symphysis. The pair of alveoli for the reception of the anterior mandibular teeth is about 15 mm in

FIG. 1. Right lateral (*a*), posterior (*b*), ventral (*c*), and dorsal (*d*) views of skull of male *Ziphius cavirostris* (HSC 57–1) stranded at mouth of Mad River, Humboldt County, California, in March of 1957. Scale is 20 cm long for dorsal view of skull.

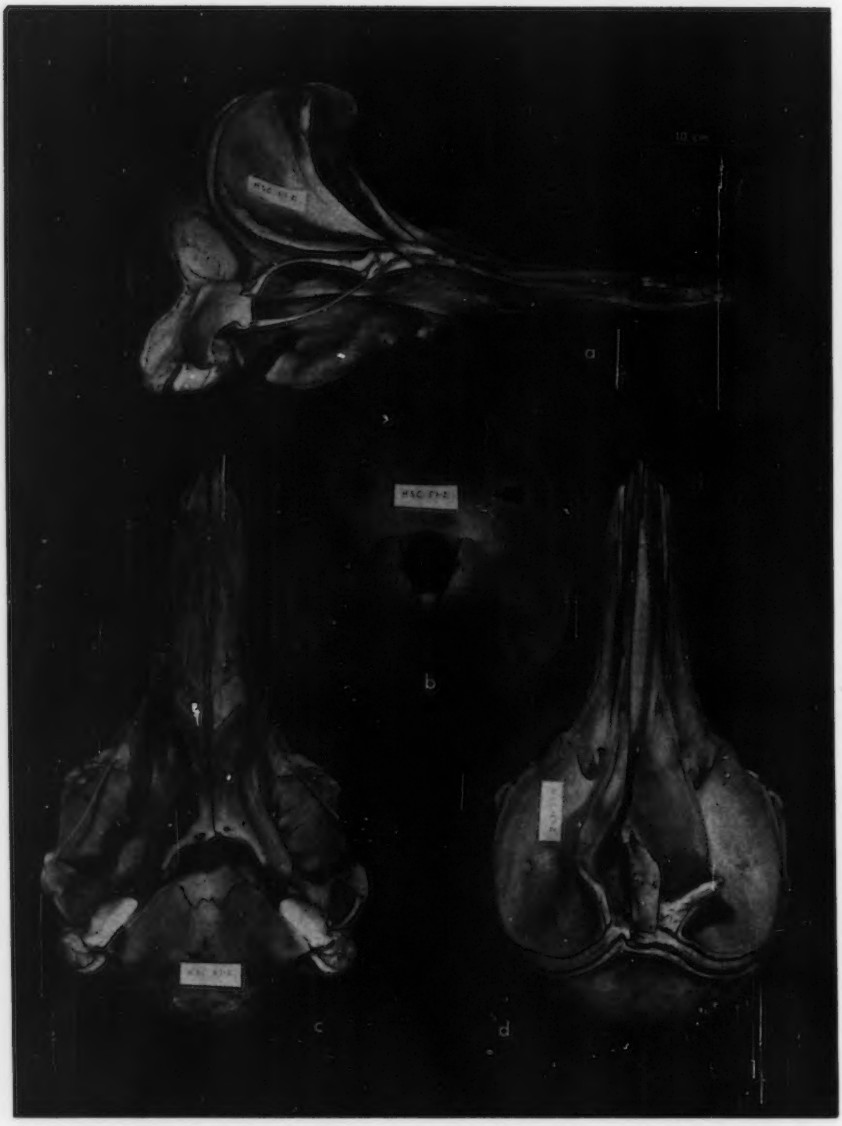

FIG. 2. Right lateral (*a*), posterior (*b*), ventral (*c*), and dorsal (*d*) views of skull of juvenile male *Ziphius cavirostris* (HSC 57–2) stranded at Big Lagoon Beach, Humboldt County, California, in November of 1957. Scale is 10 cm long for lateral view of skull.

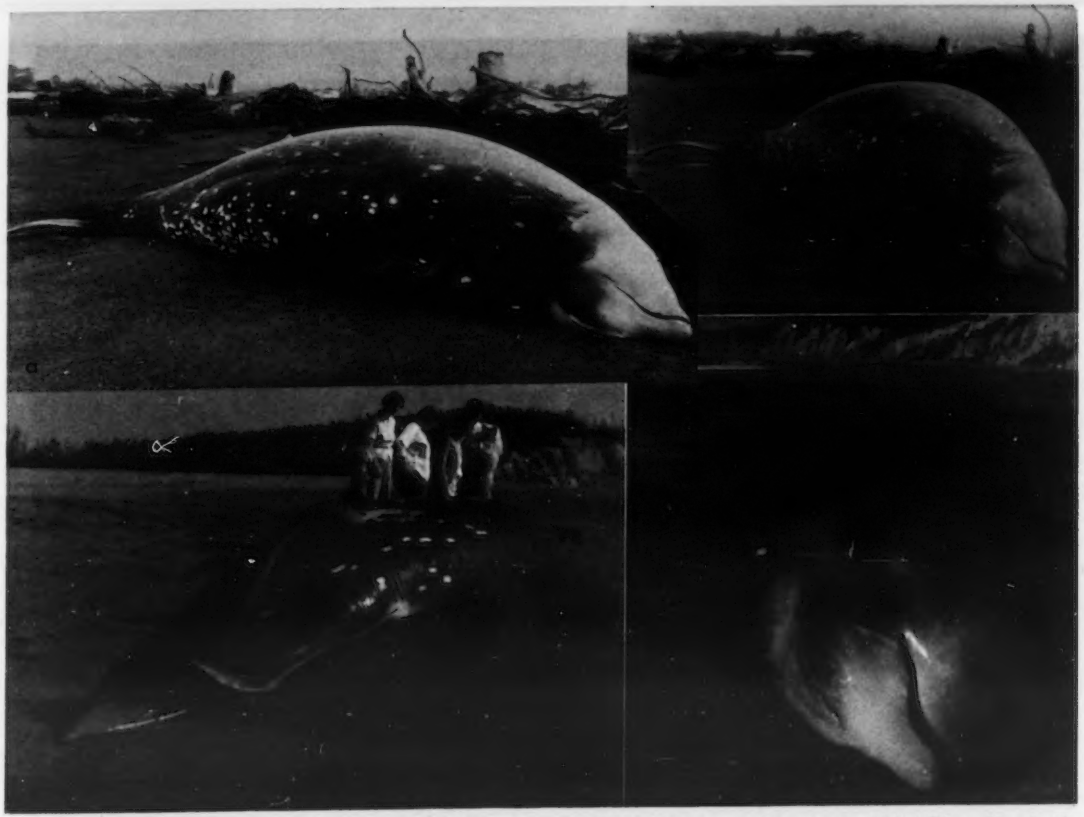

FIG. 3. Right anterolateral views (*a*, *b*) of male *Ziphius cavirostris* (HSC 57-1) stranded at mouth of Mad River, Humboldt County, California, in March of 1957. Left dorsoposterior (*c*) and anterior (*d*) views of female (HSC 59-3) stranded dead at Gold Bluff, Humboldt County, California, in September of 1959.

FIG. 4. Right lateral (*a*), posterior (*b*), ventral (*c*), and dorsal (*d*) views of skull of female *Ziphius cavirostris* (HSC 59–3) stranded at Gold Bluff, Humboldt County, California, in September of 1959. Scale is 20 cm long for lateral view of skull.

FIG. 5. Views of mandibles and teeth of northern California *Ziphius cavirostris*. Dorsal (*a*) and right lateral (*b*) views of mandible of Freshwater Lagoon individual (HSC 63-1); internal (*c*) and external (*d*) views of left mandible of Big Lagoon Beach juvenile male (HSC 57-2); lower teeth (*e*, *f*) from Freshwater Lagoon individual (HSC 63–1); dorsal (*g*) and right lateral (*h*) views of mandibles from Mad River male (HSC 57-1); dorsal (*i*) and right lateral (*j*) views of mandibles and views of lower teeth (*k*, *l*) from Gold Bluff female (HSC 59-3). Photographs to different scales; see Table III for measurements.

diameter and up to 65 mm in depth in both 59-3 and 63-1, and bears elongated, pointed teeth (see Table III and Fig. 5). The alveoli in the juvenile mandible are about 9 mm in diameter and are comparably deep, but the alveoli in the adult male are nearly filled in with bone and would not serve to seat teeth at all firmly. The symphyseal region of all of these mandibles is variable. The symphysis of the adult male is wider, the anterior tip of the mandible is more full-bodied, and the alveolar groove is not as deeply incised as in the other mandibles. The mental foramen opens onto the external surface of the mandible in front of the level of the posterior border of the symphysis in 63-1, at the same level in the juvenile male, and posterior to the symphysis in the adult male and adult female mandibles.

DISCUSSION

Kenyon (1961, pl. 2) has figured white markings on the skin of an adult female Cuvier's beaked whale, and concludes that they are too irregular to have been made by lampreys as other scars are known to be on other species of whales (Pike, 1951). Of the two freshly stranded animals herein reported, the female showed a few white oval marks on the back and flank, and Fig. 3*c* shows white markings on the left side somewhat similar to those figured by Kenyon (1961). The male shows white scratches on the back and numerous white oval markings on the side, concentrated posteroventrally near the anus. In this region some of the white marks on the male also resemble those figured by Kenyon (1961). The males of the sperm whale, *Physeter catodon*, engage in combat. Fights between adult male sperm whales have been observed, teeth have been found embedded in the skin, and the skin has been observed to carry scars or deep scratches (summary in Caldwell et al., 1966, p. 692–693). In the Ziphiidae also, white scars on the skin of *Berardius bairdi* (Omura et al., 1955; and others) and other species have been attributed to fights between males, although the idea has been disputed by some (Pike, 1953).

True (1910) concluded that coloration might vary with sex or age, but that the wide array of patterns reported for the Cuvier beaked whale from widespread localities might alternatively suggest wide individual variation. Norman and Fraser (1948) discussed the problem but concluded only that there is marked variation. We agree with Fraser (1966) that the color pattern is "inadequately known."

Omura et al. (1955) have studied *Ziphius cavirostris* in Japanese waters, and concluded that males mature at lengths of 18 ft or less (5.49 m), and females at 18 ft and over. Using these criteria, three of our four specimens represent sexually mature individuals. But Omura et al. (1955) point out that one 18-ft female was taken on August 12, 1952 that was pregnant with a 7-ft foetus, whereas another of the same length taken in November of 1949 was sexually immature. Thus length is no absolute criterion of sexual maturity. Norris and Prescott (1961) have reported a 3.40-m (11.2-ft) sexually immature female taken February 21, 1956 off southern California.

One of our specimens, the Freshwater Lagoon individual, was too badly decomposed to determine its sex but we believe that it might have been a female because the lower alveoli and teeth are like those of the Gold Bluff female in size and shape (see Table III and Fig. 5). The mandibular symphysis was fused in the Freshwater Lagoon animal, 6.50 m long, but not fused in the Gold Bluff animal, 6.22 m in length.

Kenyon (1961) found squid remains in the stomach of a 6.58-m female stranded in March 1959 on Amchitka Island, Alaska. The stomach of the 6.22-m Gold Bluff female stranded in September 1959 also contained squid remains. But Omura et al. (1955) state that a 5.49-m immature female was caught in November 1949 on a tuna long line baited with "saury Pikes." Thus both fish and squid are included in their diet.

Our data are not sufficient to allow generalizations about cranial features that might be attributed to age changes, but we can summarize some of the differences between the large male and female skulls on the one hand and the juvenile male skull on the other: On the juvenile skull the vertical median ridge dorsal to the foramen magnum is not developed on the supraoccipital shield; the occipital condylar surface is not smooth but pitted; the fontanelles between the supra- and exoccipital bones are open; the incisure between the basioccipital crest and the paroccipital process is relatively wide; the vomer is exposed on the palate in a continuous strip from between the pterygoids anteriorly to between the premaxillaries without ventral suturing or fusion of the maxillaries to form a ventral boss; the orbitosphenoid bones do not project out of the optic foramina; the jugal bones barely enter the margin of the "maxillary notch"; the posterodorsal tips of the premaxillaries are directed not anteriorly but vertically; the mandibular symphysis is unfused; and the alveoli for the anterior pair of teeth are relatively deep.

Variations relating to sex, like a massive mesorostral ossification (Fraser, 1942) coupled with a deep spiracular basin and teeth of large diameter in the male, have long been recognized in *Ziphius cavirostris* (True, 1910). These same features hold up well within our small sample, where the undoubtedly large female skull (Fig. 4) does not have an enhanced mesorostral ossification, spiracular basin, or teeth of large diameter. True (1910, p. 54–55) concluded that characters of the skull and teeth do not allow the recognition of sex in juveniles, and that females retain many characteristics of immaturity. Although we cannot contradict his findings, we found that the adult and juvenile male skulls were similar, and differed from the female skull in such features as having not a deep but a shallow sulcus around the occipital condyles, not having vertical struts in the pterygoid fossae, and having the premaxillary foramina situated anterior to the prominential notch. However, we suspect that many, if not most, of these features can be attributed to individual variation.

Perhaps all the remaining features described can be attributed to individual variation. It is certain that many cranial characters, such as those associated with arteries and veins, are susceptible to influence during early

development and can be labelled as highly variable from animal to animal. And such apparently absolute features as the broadness of the maxillary-lacrimal bone contact are also susceptible to individual variation, as Mitchell's perusal of a larger series of skulls indicates.

Indeed, the relatively wide range of age, sex, and individual variations found in *Ziphius cavirostris* might partially explain the large number of synonyms with which this species has become encumbered (cf. Hershkovitz, 1966) since attracting the attention of cetologists.

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Stomach Contents of Adult Starry Flounder and Sand Sole in East Sound, Orcas Island, Washington[1,2]

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ABSTRACT

Starry flounder fed mainly on priapulids, nemerteans, polychaetes, and lamellibranchs. Sand sole fed on fish, mysids, shrimp, and squid. Both species appeared to be daytime feeders.

Starry flounder ceased feeding during the months of lowest water temperature. This indicates that the local commercial fishery for starry flounder takes fish when they are in poor physical condition. Sand sole showed little reduction in feeding during the cold-water months.

The stomach of the starry flounder appeared to be used primarily as a holding organ and was emptied in about 9 hr. The sand sole stomach was used for digestion, which, for forage fish, took longer than 24 hr to complete.

INTRODUCTION

Food studies on flatfish have been extensive, but on the Pacific coast none of the species have been studied on a seasonal basis. Orcutt (1950) did report the change in food habits with size (age) of starry flounder, but no other detailed studies have been done.

This paper describes the stomach contents of adults of the starry flounder, *Platichthys stellatus* (Pallas), and the sand sole, *Psettichthys melanostictus* Girard, on a seasonal basis and compares the two species. Diel feeding habits are examined on the basis of data from one sampling trip.

METHODS AND MATERIALS

East Sound (Orcas Island, Washington) is a long, narrow, and shallow embayment. The area was studied in ecological detail by Gran and Thompson (1930), Phifer (1933), Weese (1935), and Wennekens (MS, 1959). However, the paper by MacPhee and Clemens (1962) on ecological groupings and habitat types presents the only treatment of fish in the area.

The East Sound study area is characterized by sluggish circulation (tidal current of about one-half knot), shallow water (about 15 fath), and a bottom sediment of silty mud, moderately compacted.

The work of Weese (1935) and Wennekens (MS, 1959) indicated that important invertebrate species in the study area were *Scalibregma inflatum*, *Sternaspis fossor*, *Nephthys* sp., *Notomastus* sp., *Dentalium rectus*, *Nucula* sp., *Phacoides tenuisculptus*, *Pandora filosa*, and *Cucumaria populifera*.

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[1]Received for publication August 12, 1966.
[2]Contribution No. 268, College of Fisheries, University of Washington, Seattle, Wash.

J. Fish. Res. Bd. Canada, 24(12), 1967.
Printed in Canada.

All collecting was done by otter trawling during the months of June, July, August, and September in 1963, and January, February, April, June, and July in 1964. Most of the trawling was done between 9:30 AM and 3:00 PM; however, in September 1963, a tow was made about every 3 hr during one 24-hr period. Captured fish were immediately sorted for sand sole and starry flounder which were estimated by eye to be 300 mm total length or longer. These were killed by a sharp blow on the head and the coelomic cavity injected with 10% neutral formalin. The injected fish were placed in plastic bags and kept cool.

This study dealt only with female fish. The ripeness of fish was assessed in the field, a "ripe" fish being one which yielded a stream of transparent ova under slight stripping pressure.

Temperature and depth of the study area were obtained with a bathythermograph. Temperature was measured to the nearest .5 C.

All species of fish and invertebrates captured in trawling and dredging operations were logged, and a reference collection was assembled as an aid to the identification of stomach contents.

Several hours after capture injected fish were placed in a refrigerator. Within a week after capture total length of the fish was measured in millimeters, otoliths (sagittae) were removed for aging, and the coelomic wall was cut open and the stomach removed. "Stomach" in this paper includes the digestive tract from immediately posterior to the pylorus to as far anterior as it is possible to cut with a pair of curved surgical scissors. No food was observed anterior to this point. Stomachs were cut open and the food items subdivided into general groups and saved for detailed examination later. Empty stomachs were discarded at this time but recorded.

Detailed examination of stomachs involved estimating their degree of fullness, identifying food organisms to the lowest possible taxonomic category, counting the organisms in each category, and determining the volumetric displacement for each category. The shells of molluscs were omitted in the volumetric determination. Other observations made during the stomach analysis were on the stage of digestion of the organisms, presence or absence of mud, position of food organisms in the stomach, condition of molluscs shells, the prominence of the stomach rugae, and the thickness of the stomach wall.

For each month (collection) individual hauls were combined before analysis. A single exception to this was for September, when only the three hauls made between 8:03 AM and 3:08 PM were grouped for the monthly analysis. Each of the eight September hauls was analyzed individually for the diel study. In making calculations of frequency-of-occurrence and volume of food organisms, empty stomachs were not included. In all cases, however, the percentage of empty stomachs is indicated.

RESULTS

The detailed results are to be found in Miller (MS, 1965). The present paper reports only the general findings.

Age-length data indicated that the majority of the starry flounder sampled were between 3 and 6 years of age and ranged in size from 306 mm to 565 mm total length. The majority of the sand sole were between 2 and 4 years of age and ranged in size from 284 mm to 454 mm. For both species, field observations on ripeness indicated that March, April, and possibly May, were the spawning months in East Sound.

There was essentially no overlap in the stomach contents of *Platichthys* and *Psettichthys* (Table I and Fig. 1). *Platichthys* fed mainly on nemerteans and priapulids, polychaetes (both errant and sedentary forms), and lamellibranchs (mainly *Yoldia* sp. and *Pandora filosa*), small crabs (Family Pinnotheridae) and brittle stars (Order Ophiura) being of minor importance. *Psettichthys* fed mainly on fish (primarily *Clupea pallasi*), mysids, shrimp, and squid playing less important roles.

Observations on food items in the stomachs indicated that *Platichthys* cracked the shells of the bivalves (except the smallest ones, which were swallowed whole), swallowed brittle stars and pea crabs whole, and swallowed whole or severed at any level nemerteans, priapulids, and polychaetes. Mud was commonly found in the stomachs of the starry flounder and occasionally bits of bark and pebbles. Stomach observations on *Psettichthys* indicated that only in rare cases were fish swallowed other than tail-first, the exception being that eel-pouts were usually doubled on themselves. Squid and shrimp were swallowed head-first whereas mysids were often in balls next to the pylorus. Mud was never found in the stomachs of sand sole except during one haul, when the net itself was accidently filled with mud.

Seasonal Changes

There appeared to be a definite seasonal trend in feeding intensity for *Platichthys* (Table II). The most intense feeding period was from about July to October or somewhat later. By January (month of the lowest bottom temperature) feeding had stopped and did not begin again until about June. Starting with the September collection of starry flounder the entire digestive tract was opened and observations made. These revealed that in collections in the months of January, February, April, and June (except three specimens) the entire digestive tract was empty. Furthermore, the stomachs were considerably shrunken, the stomach walls were very thick and muscular, and the rugae were pronounced.

Psettichthys did not show a marked seasonal change (Table II) but during January the highest percentage of empty stomachs occurred and no full stomachs were found. Sand sole were more apt to have food in their stomachs than starry flounder, even during those months when both were apparently actively feeding.

For both species the diet changed during the year. For *Platichthys* (Fig. 2) in 4 out of the 6 months of feeding, clams were the most important food item in both volume and frequency-of-occurrence. Nemerteans and priapulids were only important in the July 1964 collection. Polychaetes and pea crabs

TABLE I. Checklist of organisms from the East Sound study area, showing those found in stomachs of *Platichthys stellatus* (Pl) and those in *Psettichthys melanostictus* (Ps). Ab = abundant, Com = common.

Coelenterates
- *Cyanea capillata*
- *Stylatula* sp. (Ab)
- *Metridium* sp. (Com)
- *Cerianthus* sp. (Com)

Nemerteans — unidentified specimens (Pl)

Priapulids
- *Priapulus* sp. (Com) (Pl)

Polychaetes

Ecological group Errantia (usually free living)
- *Lepidonotus caelorus*
- *Halosydna brevisetosa*
- *Hermadion truncata*
- *Lepidasthenia longirrata*
- *Nephthys ciliata*, *N. caeca* (Ab) (Pl)[a]
- *Goniada brunnea* (Pl)
- *Glycinde armigera* (Pl)
- *Glycera americana* (Pl)
- *Anaitides groenlandica*
- *Podarke pugettensis*
- *Pilargis berkeleyi*
- *Lumbrinereis bifurcata* (Ab), *L. luti* (Com), *L. brevicirra* (Pl)[a]

Ecological group Sedentaria (usually tubicolous)
- *Prionospio pinnata*
- *P. cirrifera*
- *Spiophanes cirrata*
- *Scalibregma inflatum* (Ab) (Pl)
- *Cossura longocirrata*
- *Sternaspis fossor* (Ab) (Pl)
- *Telepsavus costarum* (Com)
- *Anobothrus gracilis*, *Amphiceteis scaphobranchiata*, *A. mucronata*, *A. glabra* (Com) (Pl)[a]
- *Terebellides stroemi* (Ab) Pl)
- *Neoamphitrite robusta*
- *Travisia pupa* (Com) (Pl)
- *Ammotrypane aulogaster* (Com) (Pl)
- *Haploscoloplos elongata*
- *Heteromastus filobranchus* (Ab), *Aricidea* (*Cirrophorus*) *branchiata*, *Notomastus* sp. (Com) (Pl)[a]
- *Pectinaria* sp. (Com) (Pl)
- *Sabellaria cementarium*
- *Euchone rosea*

Mysids
- *Neomysis kadiakensis* (Ab) (Pl) (Ps)

Amphipods — unidentified specimens (Pl)

Shrimp
- *Pandalus hypsinotus* (Ab) (Ps)
- *P. goniurus* (Ab)
- *P. borealis* (Com) (Ps)
- *Crago dalli* (Ab) (Ps)
- *C. alaskensis*

Crabs
- *Pagurus* sp. (Pl)
- *Cancer gracilis* (Ab)
- *C. productus* (Com)
- *C. magister*
- Pinnotheridae — unidentified specimens (Ab) (Pl)
- *Chionoecetes bairdi* (Com)
- *Hyas lyratus*

Gastropods
- *Natica aleutica* (Com)
- *Polinices* sp. (Com) (Pl)
- *Collumbella* sp. (Pl) (Ps)
- *Acteocina eximia* (Pl)
- *Dendronotus giganteus* (Com)
- *Armina* (*Pleurophyllidia*) *californica* (Com))
- *Tritonia* sp. (Ab)

Scaphopods
- *Dentalium* sp. (Ab)

Clams
- *Nucula tenuis* (Ab) Pl)
- *Nuculana* sp.
- *Yoldia scissurata* (Ab) (Pl)
- *Lucina* (*Phacoides*) *tenuisculptus* (Com) (Pl)
- *Tellina* sp. (Com)
- *Macoma* sp. (Pl) (Ps)
- *Compsomyax subdiaphana* (Com) (Pl)
- *Psephidia* sp.
- *Serripes groenlandicus* (Ab) (Pl)
- *Pandora filosa* (Ab) (Pl)
- *Lyonsia californica* (Com)
- *Entodesma* sp.

Squid
- *Loligo opalescens* (Com) (Ps)

(*Continued*)

TABLE I. Checklist of organisms from the East Sound study area, showing those found in stomachs of *Platichthys stellatus* (Pl) and those in *Psettichthys melanostictus* (Ps). Ab = abundant, Com = common. — (*Concluded*)

Echinoderms

Pycnopodia helianthoides (Com)
Pisaster brevispinus (Com)
Amphiodia sp. (Com) (Pl)
Strongylocentrotus drobachiensis (Com)
Parastichopus californicus
Cucumaria populifera (Ab)
Molpadia (*Caudina*) sp. (Com)
Leptosynapta sp. (Com)

Tunicates

Pyura sp.

Fishes

Hexanchus corinus
Squalus acanthias (Ab)
Raja binoculata (Com)
R. rhina (Ab)
Hydrolagus colliei
Clupea pallasi (Ab) (Ps)
Allosmerus elongatus
Spirinchus thaleichthys (Com) (Ps)
Thaleichthys pacificus
Gadus macrocephalus (Com)
Merluccius productus
Microgadus proximus (Ab) (Ps)
Theragra chalcogrammus (Ab)
Cymatogaster aggregata (Ab) (Ps)
Rhacochilus vacca
Lepidogobius lepidus
Sebastodes caurinus
Anoplopoma fimbria (Com)
Hexagrammos stelleri
Ophiodon elongatus (Com)
Blepsias cirrhosus
Chitonotus pugetensis (Com)
Dasycottus setiger
Enophrys bison
Leptocottus armatus
Myoxacephalus polyacanthocephalus
Radulinus asprellus
Scorpaenichthys marmoratus
Agonopsis emmelane
Agonus acipenserinus
Asterotheca infraspinatus
Trichodon trichodon
Delolepis gigantea
Lumpenus maculatus
Lumpenus sagitta (Ab) (Ps)
Lycodes brevipes (Ab) (Ps)
Lycodopsis pacifica (Ab) (Ps)
Palometra simillima
Citharichthys sordidus (Ab)
Atheresthes stomias
Glyptocephalus zachirus
Hippoglossoides elassodon (Ab)
Isopsetta isolepis (Ab)
Lepidopsetta bilineata (Ab)
Lyopsetta exilis
Microstomus pacificus
Parophrys vetulus (Com)
Platichthys stellatus (Ab)
Psettichthys melanostictus (Ab)
Porichthys notatus (Com)

[a]Food items not identified to species.

played a fairly consistent role in the starry flounder diet throughout the year. Brittle stars were of importance only during 2 months. The monthly analysis for *Psettichthys* (Fig. 3) indicates on a volumetric basis that fishes predominated and among these *Clupea pallasi* was the major item. However, the frequency-of-occurrence shows that mysids, and to a lesser degree shrimp, were important during the summer months whereas squid were preyed upon during the winter months. But throughout the year, fish were still consistently the most important food item.

DIEL CHANGES

For both species, the relative frequencies and volumes of food items during the September diel study differed little from those indicated (Fig. 2 and 3) for the month of September.

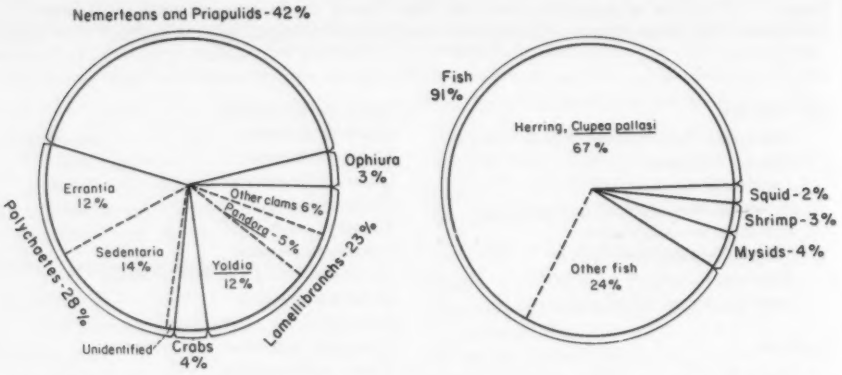

FIG. 1. Volumetric displacement of total stomach contents of *Platichthys stellatus* (*left*) and *Psettichthys melanostictus* (*right*).

Platichthys was looked at in terms of the percentage of fish with empty stomachs versus time (Table III). The starry flounder apparently began feeding about sunrise and fed through the day until about sunset. Less than 8 hr later all had empty stomachs (about half of them were empty less than 5 hr later). There was a 6-hr period when the starry flounder had essentially empty stomachs (2–3 AM to 8–9 AM).

For *Psettichthys*, both the percentage of empty stomachs versus time and the percentage of forage fish estimated to be in a particular stage of digestion are indicated (Table IV). The percentage of empty sand sole stomachs was highest, at 54, for the 5:30–6:30 AM sample and was zero about $2\frac{1}{2}$ hr later, shortly after sunrise. During daylight the percentage increased to 33. Although possible sources of error due to varying feeding intensity and small sample sizes may account for certain discrepancies in the data, generally the data indicates that sand sole fed on fish approximately between sunrise and sunset (the interval when forage fish were in an undigested state) and that complete digestion took longer than the 24-hr period of this study (since well-digested forage fish appeared in every haul). However, mysids, which were encountered in the stomachs throughout the 24-hr study nearly as often as fish were, showed little evidence of digestion except in the sample immediately before sunrise, when all mysids were well digested and broken up.

DISCUSSION

The diel study illustrates the problem of differential digestion rates for food organisms. Starry flounder appeared to empty their stomachs in 5–8 hr, but observations on the lower intestines indicated that it was here that the majority of the digestion was taking place. On the other hand, sand sole appeared to hold fish in their stomachs, where the majority of digestion took place, for more than 24 hr. Mysids either showed little effect of digestion until

TABLE II. Degrees of fullness of stomachs of *Platichthys stellatus* and *Psettichthys melanostictus* (percentages of fish in three categories) and bottom temperatures (C).

Month	Sample size	Empty	Containing some food	Full	Bottom temp
June 1963					–
Platichthys	19	63	37	0	
Psettichthys	18	33	34	33	
July					–
Platichthys	31	71	26	3	
Psettichthys	39	23	69	8	
August					12.0
Platichthys	20	50	50	0	
Psettichthys	22	4.5	77	18	
September					12.0
Platichthys	32	19	62	19	
Psettichthys	43	16	63	21	
January 1964					8.0
Platichthys	20	100	0	0	
Psettichthys	18	55.5	44.5	0	
February					9.0
Platichthys	15	100	0	0	
Psettichthys	19	26	16	58	
April					9.0
Platichthys	21	100	0	0	
Psettichthys	16	12.5	43.5	44	
June 1964					10.5
Platichthys	39	95	5	0	
Psettichthys	61	33	57	10	
July					10.5
Platichthys	31	19	42	39	
Psettichthys	14	28.5	43	28.5	
October					10.5
Platichthys	27	15	–	–	
Psettichthys	10	10	–	–	
December					9.0
Platichthys	0	–	–	–	
Psettichthys	10	20	–	–	

it was very nearly completed or were cycled through very fast. If the latter was the case, then the volumetric approach may badly underate or overate certain food organisms. In such a case the frequency-of-occurrence method would seem to be less biased.

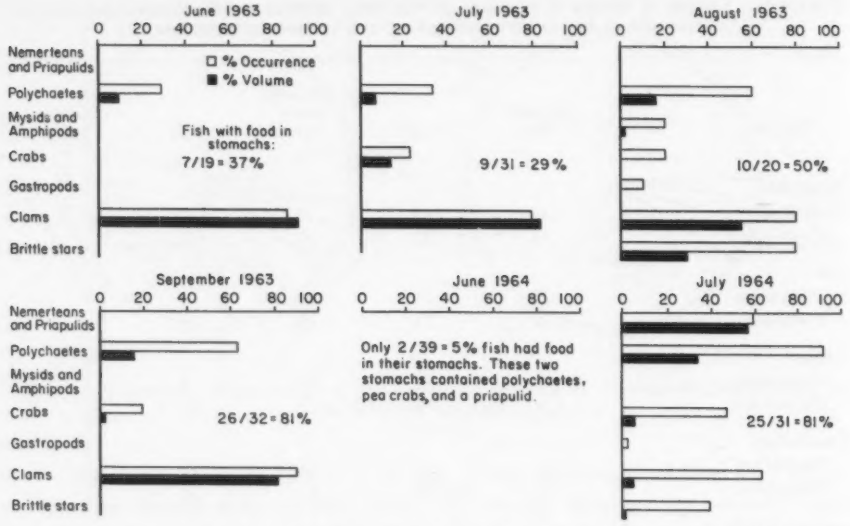

FIG. 2. Volumetric displacement and frequency-of-occurrence of stomach contents of *Platichthys stellatus*, by month.

A problem concerning the evaluation of seasonal changes in stomach contents is the possibility of starry flounder or sand sole migrating to and from the study area, thus influencing the interpretation of the results. Although no tagging was done for this project, perhaps the facts that all stages of sexual maturity were observed in an orderly sequence from month to month and that no striking changes in abundance were noted from month to month indicate some degree of permanent residency. Manzer (1952) indicated little migration for starry flounder but on the basis of very sparse data (five recoveries) did indicate the possibility of migration for sand sole.

The results of this study agree with Moiseev's (1953) observations on the Russian seas of the Pacific Ocean in that the starry flounder (a member of Moiseev's benthophagic group of flounders) and the sand sole (a predatory flounder) eat the types of food and show the seasonal changes in feeding intensity that Moiseev characterized for benthophagic and predatory flounders.

MacArthur (1964) states that two species may eat different food for only three reasons: (1) they feed in different places or at different times of the day; (2) they feed in such a manner as to capture different food; and (3) they may accept different kinds of food from among those to which they are exposed. Of course a combination of these reasons is possible. The starry flounder and sand sole apparently satisfy reasons 2 and 3. Stomach contents and morphological differences (*Platichthys* has a small, asymmetrical mouth and a small number of short, stubby gill rakers; *Psettichthys* has a large, symmetrical mouth and many long, slender gill rakers) indicate entirely different feeding

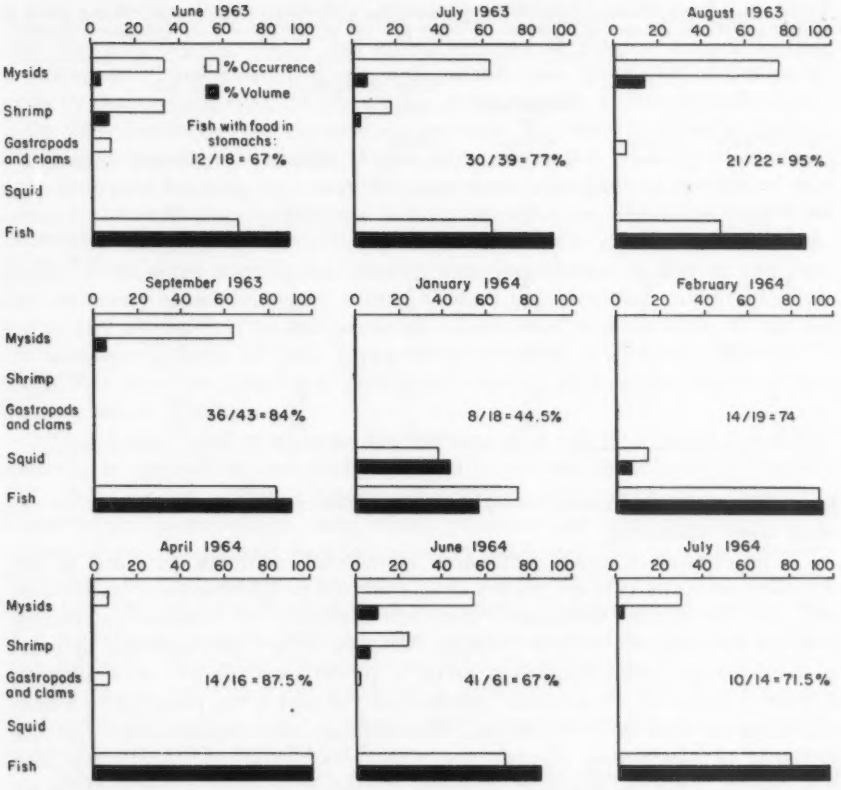

FIG. 3. Volumetric displacement and frequency-of-occurrence of stomach contents of *Psettichthys melanostictus*, by month.

TABLE III. Percentages of *Platichthys stellatus* with empty stomachs at various times in a 24-hr period.

Approximate haul time		Sample size	Percentage of empty stomachs	Remarks
AM	2–3	12	100	
	5:30–6:30	13	92	Sunrise at 6:39 AM
	8–9	15	20	
	11–12	12	17	
PM	2–3	5	20	
	5:15–6:15	12	17	Sunset at 7:06 PM
	8–9	14	29	
	11–12	11	55	

TABLE IV. Percentages of *Psettichthys melanostictus* with empty stomachs at various times in a 24-hr period, and stages of digestion of forage fish (as percentage of total forage fish present).

Approximate haul time	Sample size	Percentage of empty stomachs	Stage of digestion of forage fish			Remarks
			Slight or none	Moderate	Advanced	
AM 2–3	9	33	0	25	75	
5:30–6:30	13	54	0	0	100	Sunrise at 6:39 AM
8–9	12	0	22	0	78	
11–12	16	20	0	24	76	
PM 2–3	11	27	20	50	30	
5:15–6:15	9	33	33	33	33	Sunset at 7:06 PM
8–9	11	27	0	56	44	
11–12	17	35	0	36	64	

behavior, and there seems to be no competition between the species for the same food organisms.

The striking seasonal differences in stomach contents are hard to understand since the two species are closely related poikilothermous vertebrates, and yet one species apparently responds markedly to temperature change whereas the other shows little response. Perhaps being a benthophagic flounder is more energy conserving than being a predatory flounder, thus allowing storage of fat for the "starvation" period, but the food of the predatory flounder would appear to be more nourishing. Also, although observations on the hunting methods of piscivorous flatfish are almost non-existent, MacGinitie and MacGinitie (1949, p. 422–423) observed flatfish in shallow water dashing up from the bottom (where they were covered with mud) to catch small fish at the surface. Assuming this type of behavior to be taking place in the deeper waters, rather than an active swimming pursuit, it would appear to be highly energy conserving, unless the success of capture were very poor. Observations on the hunting methods of piscivorous flatfish would be very interesting.

The cessation of feeding of the starry flounder during the winter indicates that the commercial fishery in the Pacific northwest is operating during the period when these flounder are in their poorest physical condition. Mulicki (1947) found that the European flounder, *Platichthys flesus*, which closely resembles the starry flounder in morphology and general biology, during the winter months when food intake nearly ceased, were emaciated and had the lowest nutrition coefficient $\left(\frac{\text{Weight} \times 100}{\text{Length}^3}\right)$ and the lowest concentration of fat for the year.

Starry flounder may have been feeding selectively on lamellibranchs, since they appeared to choose thin-shelled *Yoldia* and *Pandora* almost exclusively over the abundant but thick-shelled clam *Serripes*. Blegvad (1951)

and Smidt (1951) have noted this type of selectiveness for plaice, *Pleuronectes platessa*, and Thorson (1957) has added support to Blegvad's classification of first-class (thin-shelled molluscs) and second-class (thick-shelled molluscs) foods by determining that the percentage of dry organic matter is much higher in the first-class foods than the second-class ones. The effect of selective feeding was demonstrated by Blegvad's (1928) study; first class food organisms that were protected by wire cage were 60 times more abundant at the end of the summer than the same organisms in neighboring areas where fish had been allowed to forage. Smidt (1951) reported considerable destruction to lamellibranchs and some polychaetes, relating that year-classes of *Mya* or *Cardium* may be nearly exterminated by plaice. Medcof and MacPhail (1952) felt that the winter flounder, *Pseudopleuronectes americanus*, was capable of wiping out commercial beds of seed clams, *Mya arenaria*. Villadolid (MS, 1927) considered the starry flounder, *Platichthys stellatus*, as a major enemy of the Pismo clam of California.

This study failed to disclose one instance of a fish in a starry flounder's stomach, in spite of the fact that many of the reported food items (Villadolid, MS, 1927; Orcutt, 1950; Clemens and Wilby, 1961) such as *Lycodopsis*, *Cymatogaster*, *Citharichthys*, and young pleuronectids were abundant in a variety of size ranges and were fed upon by sand sole. This investigator does not believe that fish are an important part of the starry flounder diet. However, aquarium observations demonstrated that starry flounder would feed on fish in a scavenging manner, and this may happen occasionally in nature; also, such fish as the burrowing *Ammodytes* could be preyed upon in the same manner as polychaetes are. Generally speaking, it is difficult to believe that the morphology of the mouth, teeth, and gill rakers would allow the starry flounder to be very successful at catching fish.

Sand sole fed on a rather restricted number of fish species and among these species herring was clearly the most utilized. Incidental stomach analyses by this investigator in other parts of Puget Sound (Port Orchard, Golden Gardens, and Bellingham Bay) indicate that adult sand sole are primarily piscivorous in these areas too. From this it is concluded that Clemens and Wilby (1961) are probably in general error on the food habits of the sand sole, as was indicated earlier by Smith's (1936) data.

ACKNOWLEDGMENTS

I would like to thank the following of the University of Washington: Dr Allan C. DeLacy for interest and advice throughout this project and for reviewing the manuscript; Dr Kenneth K. Chew for help in identification and classification of invertebrates and for reviewing the manuscript; and Dr Robert L. Fernald for facilities at the Friday Harbor Laboratories. Dr Boyd W. Walker, University of California at Los Angeles, and Dr S. R. Wellings, University of Oregon Medical School, cooperated in the scheduling of boat trips for me. Mr William H. Hardman, International Pacific Halibut Commission, gave help on aging procedures. Mr Cleave C. Vandersluys,

skipper of the research vessel *Hydah*, was invaluable to the successful completion of this project. My wife, Aase Marie, assisted me in the field and lab, and typed the manuscript. A part of this study was supported by a grant under Initiative 171, a Washington State sponsored program for biological and medical research.

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Exploitation of Multiple Stocks by a Common Fishery[1]

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ABSTRACT

A complete analytical solution is presented for the problem of finding the common rate of exploitation that maximizes total sustained yield from a mixture of stocks when each stock follows a Ricker reproduction curve. A computer program is described which solves this problem for up to 20 stocks varying in both reproductive potentials and absolute sizes. Some aspects of the management of Pacific salmon and fishing strategies are discussed in relation to the question of obtaining maximum yields when harvesting mixtures of stocks under various constraints.

INTRODUCTION

In his pioneering study of the amount of recruitment produced by various sizes of parent populations, Ricker (1954) found that reproduction curves for a number of different animals were dome-shaped and asymmetrical. He derived from theoretical considerations a mathematical formula which has since proven to be well suited for describing the manner in which the number of recruits produced changes as the density of the parent spawning population changes. Ricker's reproduction curve for a single population is

$$Z = We^{a(1-W)} \qquad \ldots\ldots(1)$$

when Z is the progeny and W the parental generation, both expressed as fractions of the replacement stock size (the size of the adult stock which in the absence of exploitation just reproduces itself); and a is the ratio of the replacement stock size to the level of parental stock required for maximum reproduction. By varying the values of these two parameters, Ricker and later investigators have been able to use equation 1 to obtain close agreement with field data collected from different populations of fishes.

For the Pacific salmons (*Oncorhynchus*) equation 1 is rapidly becoming a standard management tool. The use of this curve for determining harvesting strategies is outlined in detail by Ricker (1958a) and Murphy (1966). Paulik and Greenough (1966) reviewed this technique for managing salmon stocks and presented some extensions. It has become evident that values of the ratio a which is a measure of the reproductive potential of a population may vary considerably from one population to another of the same species of salmon.

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J. Fish. Res. Bd. Canada, 24(12), 1967.
Printed in Canada.

Populations whose separate identities are genetically maintained will be referred to as stocks and, for the sake of definiteness, the problem will be discussed as one of harvesting a run of salmon composed of one or more stocks (cf. with definitions presented by Ricker, 1962, p. 158). By the use of either mark-recapture experiments or morphometric and meristic characters (Worlund and Fredin, 1962), it is often possible to divide the catch of a fishery into the components contributed by individual stock units. When spawning escapements of various stocks are geographically or temporally distinct, the results of spawning ground surveys may be combined with catch sampling to provide data for estimating recruitment curves for individual stocks in a common fishery. Ocean and estuarine fisheries for salmon commonly exploit mixtures of stocks. Fisheries conducted in the lower reaches of a large river may simultaneously exploit a run composed of a number of distinct stocks spawning in upstream tributaries.

The consequences to stock recruitment relationships when several stocks are exploited by a common fishery were briefly considered by Ricker (1958b). Ricker's treatment of this problem was primarily graphical. He dealt with the case of three stocks, all of which had the same replacement stock size. He showed that some individual stocks might be harvested at a rate that did not produce their individual maximum sustained yields, and that it may be possible to obtain the total maximum sustained yield from a mixture of stocks only by fishing at a rate which exterminates one or more of the stocks. Doi (1962) employed an analytical procedure to examine the yield produced by harvesting at different rates two stocks from a single river system.

In this paper we present a complete analytical treatment of the problem of determining the common rate of exploitation that will produce the maximum total equilibrium yield from a mixture of stocks when each of the individual stocks is governed by a separate Ricker reproduction curve. The stocks may differ in both reproductive potential (parameter a) and in absolute magnitude (replacement stock size). It will be assumed that estimates of both of these parameters are available for each stock. The gain in total yield realized by fishing and regulating each stock separately will also be examined. A computer program that makes it possible to examine a number of other fishing strategies, such as maximizing the total equilibrium yield of a mixture of stocks subject to the restraint that the rate of exploitation will always be less than that which will exterminate any of the stocks, is presented.

Throughout this paper the subject is developed with particular reference to Pacific salmon for which joint fisheries on mixtures of stocks are commonplace. However, there are obvious applications to the management of other species of fish and, more generally, to harvesting of mixtures of populations of other animals in which recruitment considerations are predominant.

CALCULATION OF MAXIMUM SUSTAINED YIELD

Equation 1 is easily extended to represent the total number of recruits (Z_T) from a combination of n stocks.

$$Z_T = \Sigma Z_i = \sum_{i=1}^{i=n} A_i W_i e^{a_i(1-W_i)} \quad \ldots\ldots(2)$$

where $i = 1, \ldots, n$ and A_i are coefficients associated with relative magnitudes of stock sizes at replacement levels. The A_i may be used to convert stock units into absolute numbers of fish or as more general weighting factors that might incorporate, for example, the relative values of the fish of different stocks.

The spawning population size (E_i) associated with a sustained yield (C_i) at a given rate of fishing on a particular stock is given by

$$E_i = A_i W_i \quad \ldots\ldots(3)$$

and the sustained yield (C_i) by

$$C_i = Z_i - E_i = A_i W_i{}^{a_i(1-W_i)} - A_i W_i \quad \ldots\ldots(4).$$

If the stocks are harvested separately, the total maximum sustained yield (C_T) is the sum of the individual maximum sustained yields. The number of spawners for each stock that will produce the maximum total yield may be found by setting to zero the partial derivatives with respect to W_i of the expression

$$C_T = \sum_{i=1}^{i=n} C_i = \sum_{i=1}^{i=n} [A_i W_i e^{a_i(1-W_i)} - A_i W_i] \quad \ldots\ldots(5).$$

Where the stocks are harvested jointly, it is necessary to solve equation 5 for values of W_i when the ratio of catch to stock size is the same for all stocks, i.e., there is a common rate of fishing (u) and a common rate of escapement from the fishery ($r = 1 - u$). Algebraically,

$$\frac{A_1 W_1}{A_1 W_1 e^{a_1(1-W_1)}} = \ldots = \frac{A_i W_i}{A_i W_i e^{a_i(1-W_i)}} = \ldots = \frac{A_n W_n}{A_n W_n e^{a_n(1-W_n)}} \quad \ldots\ldots(6).$$

Thus, in terms of stock 1

$$W_i = \frac{a_i - a_1 + a_1 W_1}{a_i} \quad \ldots\ldots(7).$$

For two stocks with $a_1 > a_2$,

$$W_2 = \frac{a_2 - a_1 + a_1 W_1}{a_2} \quad \ldots\ldots(8)$$

where W_1 is defined for $r_1 < r \leq 1$; and W_2 is defined for $r_1 < r_2 < r < 1$; where

r_1 and r_2 are the lowest survival rates from the fishery at which the respective stocks will not become extinct.

Assuming W_1 represents the stock that can support the highest rate of exploitation, each of the other W_i may also be expressed in terms of W_1 (e.g., equation 8). Substituting these expressions in equation 5 and differentiating with respect to W_1 gives the value of W_1 associated with the maximum combined yield when the stocks are harvested jointly. Values of the various W_i associated with the maximum combined yield are then directly available from equation 7. These values for the surviving stocks may, in turn, be substituted in equation 5 to determine the maximum sustained yield for the combined fishery.

Alternative Terminology

The terminology in the foregoing treatment follows that of Ricker (1958a). A more flexible and general terminology for stock recruitment relationships has been developed by one of the authors (Paulik) utilizing an approach similar to that of Ricker (1954).

The relationship between stock and recruits may be generally defined by

$$N_{t+\tau} = N_t s_{(t,t+\tau)} \qquad \ldots\ldots(9)$$

where N_t is the number of individuals in the stock at time t; τ is the duration of the life span; $s_{(t,t+\tau)}$ is the fraction surviving from t to $t+\tau$.

Assuming that the number of eggs produced by the stock is proportional to the number of spawners (S), we can write

$$R = fSs_{(0,\tau)} \qquad \ldots\ldots(10)$$

where f is the number of eggs per spawning unit; S is the number of spawning units; R is the number of mature progeny of the spawners represented by S. In the case of a coastal Pacific salmon fishery, R is also virtually the same as the number of recruits.

If mortality is compensatory, $s_{(0,\tau)}$ is a monotonic decreasing function of S, which may be written $s(S)$. If $s(S)$ is a negative exponential function

$$s(S) = \lambda e^{-\beta S} \qquad \ldots\ldots(11)$$

by substitution in equation 10, and setting $f\lambda = \alpha$, Ricker's stock recruit curve is obtained in the form

$$R = \alpha S^{-\beta S} \qquad \ldots\ldots(12).$$

Comparing equation 12 with the other terminology, viz.

$$Z = AWe^{a(1-W)} \qquad \ldots\ldots(13)$$

the relationships between terms are

$$\begin{aligned} \alpha &= e^a \\ \beta &= a/A \\ S &= AW \end{aligned} \qquad \ldots\ldots(14).$$

This more general notation is closely related to the least-squares method for fitting reproduction curves to observed data. The linear relationship obtained from equation 12 by dividing by S and taking logarithms is

$$ln\left(\frac{R}{S}\right) = ln\,\alpha - \beta S \qquad \ldots\ldots(15)$$

and may be employed to estimate α and β.

For this notation the restrictions on the parameters are

$$\alpha \geq 1 \text{ and } \beta \geq 0.$$

The maximum number of recruits is obtained when

$$S = \frac{1}{\beta} \qquad \ldots\ldots(16)$$

and the number of recruits at this maximum

$$R_{(max)} = \frac{\alpha}{\beta e} \qquad \ldots\ldots(17)$$

where e = 2.718.

The reproduction curve intersects the replacement line at the point

$$S = R = \frac{ln\,\alpha}{\beta} \qquad \ldots\ldots(18).$$

With displacement from equilibrium at this point, the stock will return to equilibrium by a dampened oscillation if, in the region of intersection, the slope dR/dS is greater than -1 (in this instance $\alpha < e^2$). If $dR/dS < -1$ the population will oscillate about equilibrium if displaced.

Using this terminology, equation 5 describing the summed catch when harvesting a number of stocks separately is given as

$$C = \sum_{i=1}^{i=n} C_i = \sum_{i=1}^{i=n} [\alpha_i S_i e^{\beta_i S_i} - S_i] \qquad \ldots\ldots(19).$$

In the case of joint harvesting for maximum combined yield, equation 19 is solved for the values of S_i associated with the maximum combined yield with the restraints that

$$(1)\quad \frac{S_i}{\alpha_i S_i e^{-\beta_i S_i}} = (1-u) \qquad \ldots\ldots(20)$$

where $i = 1, \ldots, n$ and

$$(2)\quad C_i \geq 0.$$

A method of finding the S_i values that maximize C_T under these restrictions is included in the following description of a computer program.

COMPUTER PROGRAM

The maximum equilibrium yield for each stock separately is found by solving each of the equations

$$\frac{\partial C_T}{\partial S_i} = 0 \qquad \ldots\ldots(21)$$

for $i = 1,\ldots,n$. The i^{th} equation is

$$\frac{\partial C_T}{\partial S_i} = \alpha_i e^{-\beta_i S_i} - \alpha_i \beta_i S_i e^{-\beta_i S_i} - 1 = 0 \qquad \ldots\ldots(22).$$

The unique values of S_i that will satisfy these equations lie between $S_i = 0$ and $S_i = ln\ \alpha_i/\beta$. These values of S are used as starting points in the iterative scheme based upon the simple linear interpolation

$$S_i^{(j+1)} = \frac{\left(\frac{\partial C_T}{\partial S_i}\right)^{(j)} S_i^{(j-1)} - S_i^{(j)} \left(\frac{\partial C_T}{\partial S_i}\right)^{(j-1)}}{\left(\frac{\partial C_T}{\partial S_i}\right)^{(j)} - \left(\frac{\partial C_T}{\partial S_i}\right)^{(j-1)}} \qquad \ldots\ldots(23)$$

where $(\partial C_T/\partial S_i)^{(j)}$ is the value of the partial derivative evaluated at the point $S_i = S_i^{(j)}$ and $S_i^{(j)}$ is the j^{th} value of S_i found by iteration. Iteration is continued until $(\partial C_T/\partial S_i)^{(j)} < 10^{-\Delta}$ where Δ is entered as a control parameter by the user. Thus the value of S_i that satisfies $\partial C_T/\partial S_i = 0$ ($S_i = S_i^*$ at this point) may be found to any degree of accuracy desired. The total catch which is a function of the n S's attains a maximum at the point

$$(S_1 = S_1^*, S_2 = S_2^* \ldots, S_n = S_n^*) \qquad \ldots\ldots(24).$$

It is obvious that harvesting each stock separately will produce a higher equilibrium yield than any other for this system.

When stocks are harvested jointly, the solution for the maximization problem of equations 19 and 20 proceeds by ranking the n stocks according to their α_i values. Assuming that the n^{th} stock has the largest α value, the $n-1^{th}$ the second largest, and so on, the common rate of exploitation restriction implies the equation

$$S_i = \frac{1}{\beta_i} ln\ (\alpha_i/\alpha_n) + (\beta_n/\beta_i)\ S_n \qquad \ldots\ldots(25)$$

in any interval on the S_n axis where S_i exists; otherwise, $S_i = 0$. Employing

equations 19 and 25, C_T may be expressed as a function of S_n. The restriction that only positive equilibrium catch values are meaningful defines a series of intervals on the S_n axis. The equilibrium rate of exploitation is a decreasing monotonic function of S_n. The first interval extends from $S_n = 0$ to $S_n = (1/\beta_n)\ ln\ (\alpha_n/\alpha_{n-1})$. When S_n is below $(1/\beta_n)\ ln\ (\alpha_n/\alpha_{n-1})$, i.e., the rate of exploitation exceeds $1-1/\alpha_{n-1}$, the stock with the second largest α (and all of the other n-2 stocks with smaller α's) cannot survive. In the second interval, where S_n is between $(1/\beta_n)\ ln\ (\alpha_n/\alpha_{n-1})$ and $(1/\beta_n)\ ln\ (\alpha_n/\alpha_{n-2})$, only stocks n and n–1 contribute to the catch. This process is continued until the n^{th} interval is reached in which all n stocks survive.

The number of stocks that are represented in the derivative $(\partial C_T/\partial S_n)$ is equal to the number of stocks surviving in the interval in the S_n axis for which the derivative is defined. Consequently it is necessary to solve the equation $\partial C_T/\partial S_n = 0$ for each such interval. An iterative procedure similar to that described above is used to find the S_n that satisfies $\partial C_T/\partial S_n = 0$ for each interval. If the maximum does not exist in the interior of the interval, the catches at the end points are compared and the largest of these is taken as the maximum catch for the interval. The largest of these interval maxima is then the maximum equilibrium catch that can be achieved under the common rate of exploitation restriction.

In most actual fishery situations some modification in the above procedure would be required to account for partial segregation of stocks (on the basis of timing), changes in management practices, and so on.

An Example Problem

The form of the computer output is briefly illustrated for a modification of the example used by Ricker in his 1958 paper on the maximum sustained yield from mixed stocks. A more comprehensive description of this computer program with a number of worked examples will be presented elsewhere. Ricker considered a hypothetical run composed of three stocks with reproductive potentials of 1.0, 2.0, and 2.678 and the same replacement stock sizes. Ricker's example was modified by letting the stock with the highest reproductive potential (stock 3) have a replacement stock size five times as great as the other two stocks.

Table I is a summary of the results of the computer analysis. Stock numbers 1, 2, and 3 correspond to Ricker's stock numbers A, B, and C respectively. If the stocks are fished separately, the maximum total sustained yield is 9.55 (the sum of the individual stock maxima). The optimum rates of exploitation for the three stocks are .4329, .7215, and .8407 respectively.

The combined run strategy shown in the middle of Table I gives the yield that could be expected if the stocks were fished to provide a spawning escapement from the total run equal to the sum of the optimum escapements for the individual stocks. Here the common rate of exploitation of .8017 leads to the extinction of stock 1. The total catch produced by this strategy is 8.77.

TABLE I. Summary computer tabulation of catch, escapement, and run for each of the three stocks as in Fig. 1, and the total, in hypothetical fisheries of three types, (1) stocks fished separately; (2) stocks mixed with provision for a total spawning escapement equal to the sum of the optimum escapements for the individual stocks; and (3) stocks mixed and harvested to produce a maximum sustained yield.

	Stock No.	Catch	Spawners	Run	Rate of exploitation	Long-term behavior
Fished separately	1	0.330	0.433	0.763	0.4329	
Total catch computed as a sum	2	0.935	0.361	1.296	0.7215	
of maximum equilibrium catches	3	8.287	1.570	9.857	0.8407	
for the individual stocks						
Total		9.552	2.363	11.916	Avg = 0.6650	
Combined run	1	0.000	0.000	0.000		Extinct
Total catch computed by har-	2	0.772	0.191	0.964		Stable
vesting each stock according to	3	8.001	1.980	9.980		Stable
the combined rate of exploitation (U(C) = 0.8017)						
Total		8.773	2.171	10.944		
Mixed fishery	1	0.000	0.000	0.000		Extinct
Maximum yield for mixture of	2	0.650	0.143	0.792		Stable
stocks; rate of exploitation =	3	8.192	1.798	9.991		Stable
0.8200						
Total		8.842	1.941	10.783		

At the bottom of Table I the common rate of exploitation that produces a maximum yield for this particular mixture of stocks is shown to be .8200. There is an increase in total catch from 8.77 to 8.84 over the combined-run fishing strategy. It can also be seen that if the fishing regulations were modified to allow separate exploitation of individual stocks, the maximum total sustained catch could be increased from 8.84 to 9.55.

Figure 1 is a plot of total equilibrium catch for the mixture of stocks as a function of the common rate of exploitation. The equilibrium catch curves for each of the three stocks are also given. In the original CalComp computer plots the catch curves for the different stocks are plotted in different colors. In the figure, labels identifying the stocks have been added to substitute for identification by color. Figure 1 shows that if the exploitation rate is greater than 63.2%, stock 1 is exterminated. The cost in terms of potential catch of harvesting at a rate of exploitation low enough to allow stock 1 to survive is easily determined from this type of graph. A computer program which will carry out the analyses described in this paper and instructions for its use may be obtained free of charge by writing to the Data Analysis Section of the Fisheries Research Board of Canada, Biological Station at Nanaimo, B.C.

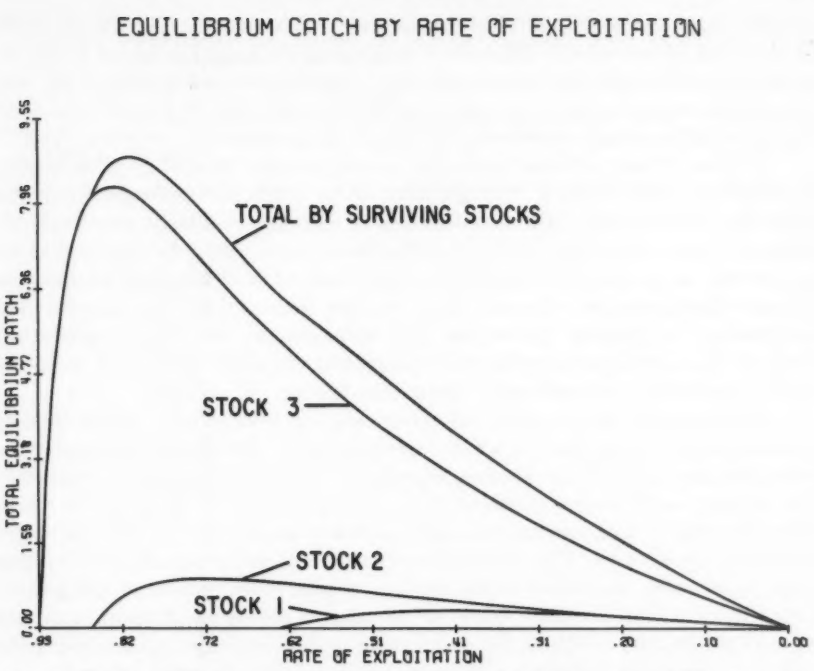

FIG. 1. Total equilibrium catch at various rates of exploitation in a hypothetical fishery on three mixed stocks with reproductive potentials of 1.0 (stock 1), 2.0 (stock 2), and 2.678 (stock 3), and with stock 3 with a replacement size five times as great as stocks 1 and 2. The figure is a direct reproduction from a CalComp computer plot.

DISCUSSION

In the management of salmon fisheries on mixed stocks it is apparent that many alternative fishing strategies might be devised in reconciling yield of fish with economic and practical considerations, and that the kind of approach employed in this paper could be extensively elaborated. Greatest sustained yield is associated with harvest of each stock separately. Where the fish enter a common fishery, rates of fishing associated with maximum yield can be obtained by procedures of evaluation similar in concept to those here developed. With computer assistance there are available quick solutions for these kinds of problems. In general the greater the differences in productivity and size of salmon stocks, the more important it becomes to carefully evaluate the best strategy and rate of fishing to obtain maximum yield.

It is also apparent that different management strategies which result in similar sustained yields may have markedly different effects on the relative abundance of the individual stocks making up the total run to the fishery. Under such circumstances the desirability of preserving a broad genetic level of response to environmental change within a salmon run might mitigate

against the application of those strategies which over-exploit small stocks to the level of extinction. Since each stock may be highly adapted to its individual environment, the preservation of a nucleus of each genotype for possible future expansion through different fishing strategies or by artificial techniques could pay large dividends in future production.

Further, it may often be desirable to evaluate the feasibility of increasing the size of a salmon stock by regulation or by artificial enhancement in the prevailing circumstance of a mixed fishery or fisheries. Similarly, the establishment of a new and highly productive hatchery stock might be responsible for an increase in the rate of exploitation that resulted in elimination of less productive existing stocks harvested in a common fishery. Effective coordination of attempts to increase production and management activities requires analysis of the interaction between the fishery and the entire system of exploited stocks (including perhaps more than one species of salmon).

Consideration of an entire salmon-producing system as a whole focuses attention upon the manner in which management of the harvesting machinery influences the value of the system to society. To plan for effective utilization of a resource such as a watershed, it is often necessary to compare its worth when devoted to a competing use such as power production against its worth for salmon production. The value of past salmon yields produced by a system is apt to be more a measure of the quality of past management of the system rather than of the intrinsic value of its salmon resources. A more accurate measure of the true worth of fish production is the maximum sustainable yield that the system can produce under an optimum management program.

ACKNOWLEDGMENTS

An early preliminary version of the computer program was written by Mrs Dina Barzell who is a staff member of the computer center at the University of Washington. Mr Allan Walker of the Fisheries Research Institute at the University of Washington coded several intermediate versions and the final version of this program. He also prepared the CalComp plot routine.

The work of G. J. Paulik was supported in part with funds provided by the Department of the Interior, Office of Water Resources under P.L. 88-379.

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Lamprey Parasitism of Rainbow Trout in Southern Georgian Bay[1,2]

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ABSTRACT

Of 2614 adult rainbow trout sampled from the Nottawasaga River of Georgian Bay during the period of 1961–67 inclusive, approximately 7.1% had one or more lamprey marks. The trout ranged in fork length from 10 to 33 inches (25 to 84 cm). However, lamprey marks were present only on fish over 16 inches (40 cm) in length. Multiple scarring was found on 30% of the trout that were marked. The incidence of marked fish reached a maximum of 17.2% in the spring of 1962, then declined to 1.3% in the fall of the same year. This decline was coincident with a reduction in the lamprey population after experimental lampricide treatment of the Nottawasaga River and adjacent lamprey spawning streams during 1960 and 1961. The incidence of marked fish remained at a relatively low level for a period of 4 years, then increased substantially, after the presumed recruitment of metamorphosed lampreys during 1966 and 1967.

INTRODUCTION

The lake trout, *Salvelinus namaycush* (Walbaum), of the Great Lakes has proved to be very vulnerable to parasitism by the sea lamprey, *Petromyzon marinus* Linnaeus. The Lake Huron population of lake trout was virtually eliminated by the lamprey in the early 1950's (Fry, 1953; Appelgate and Moffett, 1955). The rainbow trout, *Salmo gairdneri* Richardson, which has become widely distributed in the Great Lakes since its introduction near the end of the last century (MacKay, 1963), is also parasitized by the sea lamprey. However, in spite of the importance and interest in this species as a game fish, little attention has been directed to the degree or effects of parasitism by the lamprey on this species in the Great Lakes.

This paper presents data on lamprey parasitism of a sample of 2614 adult rainbow trout from the Nottawasaga watershed of Georgian Bay during 1961–67 inclusive. The lampricide treatment of lamprey spawning streams in southern Georgian Bay by the Fisheries Research Board of Canada during the early part of the study provided an opportunity to make "before and after" comparisons of the incidence of lamprey marks on rainbow trout.

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[1]Received for publication June 14, 1967.
[2]Contribution No. 67-14 of the Ontario Department of Lands and Forests, Research Branch, Maple, Ontario.

J. Fish. Res. Bd. Canada, 24(12), 1967.
Printed in Canada.

DESCRIPTION OF STUDY AREA

The Nottawasaga River (Fig. 1) is a large tributary of Georgian Bay with a summer flow of about 400 ft^3/sec (11,320 liters/sec). The main branch originates in the vicinity of Shelburne and enters Georgian Bay at Wasaga Beach, a distance of approximately 100 miles (161 km) to the northeast.

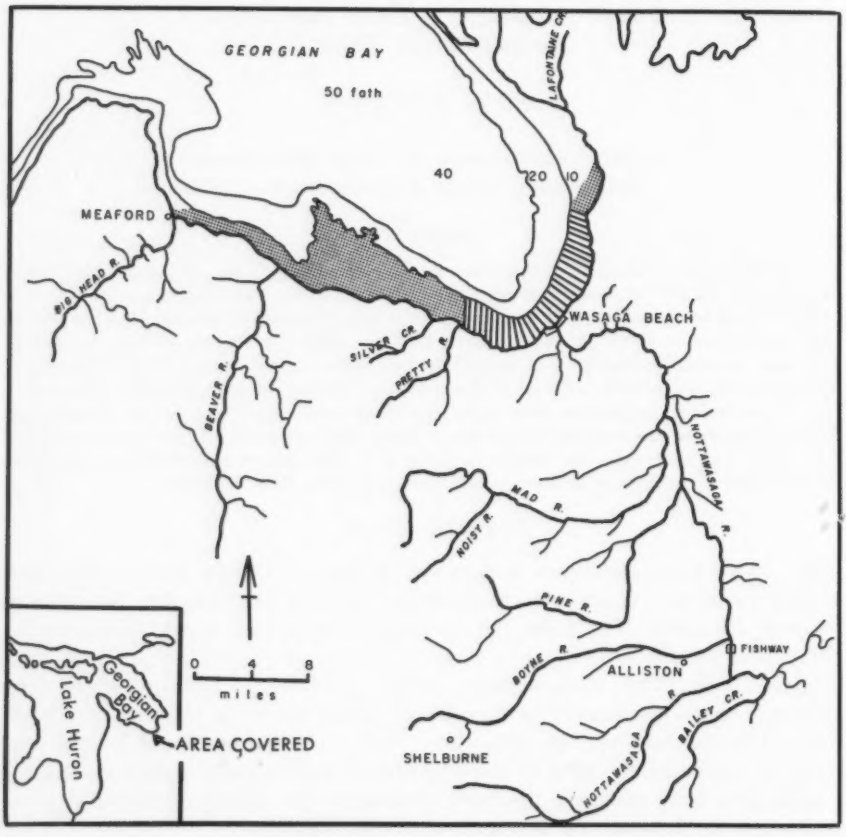

FIG. 1. Southern section of Georgian Bay showing principal river systems and inferred distribution of Nottawasaga River rainbow trout in the bay. Vertical bars, main concentrations; stippled areas, lower densities.

The river system is used extensively for spawning by rainbow trout and lamprey populations of Georgian Bay, and serves as a nursery for the early stages of both species.

The Nicolston dam, on the main branch of the Nottawasaga River near Alliston, marks the upper limit of sea lamprey distribution in the watershed

(A. Lamsa, personal communication). A fishway located beside the dam facilitates the upstream passage of adult rainbow trout to spawning areas in the upper reaches of the river.

The Nottawasaga River was treated with lampricide by the Fisheries Research Board of Canada in June 1961. All other known lamprey streams in Georgian Bay, including Silver Creek and La Fontaine Creek (Fig. 1), were treated the preceding summer and fall (Cucin and Regier, 1965).

METHODS

The Lake Simcoe District staff of the Ontario Department of Lands and Forests has maintained the fishway at the Nicolston Dam on the Nottawasaga River (Fig. 1) since April 1961 (Wainio, 1962). An elevator-type cage, located near the upstream end of the structure, makes possible the capture of fish entering the fishway. The periods during which the fishway was operated for the present study were as follows: 1961 — April 15 to May 12, and September 12 to November 30; 1962 — March 31 to May 7, and October 10 to November 21; 1963 — April 2 to May 14, and September 18 to November 25; 1964 — March 21 to May 11; 1965 — April 2 to May 9; 1966 — March 19 to May 8; 1967 — April 5 to May 7.

During the period of 1961–67 inclusive 723 male and 1891 female adult rainbow trout which passed through the fishway were measured, tagged with streamer-type tags, and released above the dam. Sex was determined by the observation of secondary sexual characters. Scale samples were taken from the right side of the body above the lateral line and below the origin of the dorsal fin. The numbers of open and healed lamprey marks were recorded for each specimen during the entire study. In addition, the locations of lamprey marks (Fig. 3) were recorded for all specimens examined from 1962 to 1967 inclusive. Data on the locality of capture and size of recaptured (tagged) rainbow trout were obtained by creel censuses of anglers and by voluntary returns from anglers and commercial fishermen.

OBSERVATIONS

Of the 2614 trout examined, 185 (7.1%) had one or more scars (Table I). Only 9 (0.3%) of the fish bore raw wounds. The proportions of marked male and female rainbow trout were 6.3% and 7.2% respectively.

A relationship between parasitism and fish size is shown in Fig. 2. The trout examined ranged from 10 to 33 inches (25 to 84 cm). Lamprey marks were found only on fish over 16 inches (40 cm) in length. The incidence of marking on fish in the various 1-inch (25-mm) length classes ranged from 0 to about 6% of the sample. There was a general increase in mean lengths of both male and female rainbow trout during the first 6 years of the study. In the final year, this trend reversed. The mean annual lengths of male fish were consistently shorter than those of females by 1 to 2 inches.

The upward trend in the percentage of rainbow trout bearing lamprey marks with increase in length of the fish is apparent in the pooled data of

TABLE I. Incidence of lamprey marks on rainbow trout from the spawning population of the Nottawasaga River, 1961–67.

Time period	Total fish of both sexes	Males				Females			
		Total no.	No. with raw wounds	No. with healed wounds	% marked	Total no.	No. with raw wounds	No. with healed wounds	% marked
Spring 1961	578	172	0	12	7.0	406	2	31	8.1
Fall 1961	53	18	0	2	11.1	35	0	5	14.3
Spring 1962	354	90	1	19	22.2	264	1	40	15.5
Fall 1962	217	98	0	3	3.1	119	0	0	0
Spring 1963	200	56	0	1	1.7	144	0	12	8.3
Fall 1963	157	99	0	1	1.0	58	1	1	3.4
Spring 1964	297	68	0	2	2.9	229	1	11	5.2
Spring 1965	284	51	0	0	0	233	0	2	0.9
Spring 1966	255	35	0	0	0	220	0	13	5.9
Spring 1967	219	36	1	4	13.9	183	2	17	10.4
Totals	2614	723	2	44	6.3[a]	1891	7	132	7.2[a]

[a]Average per cent.

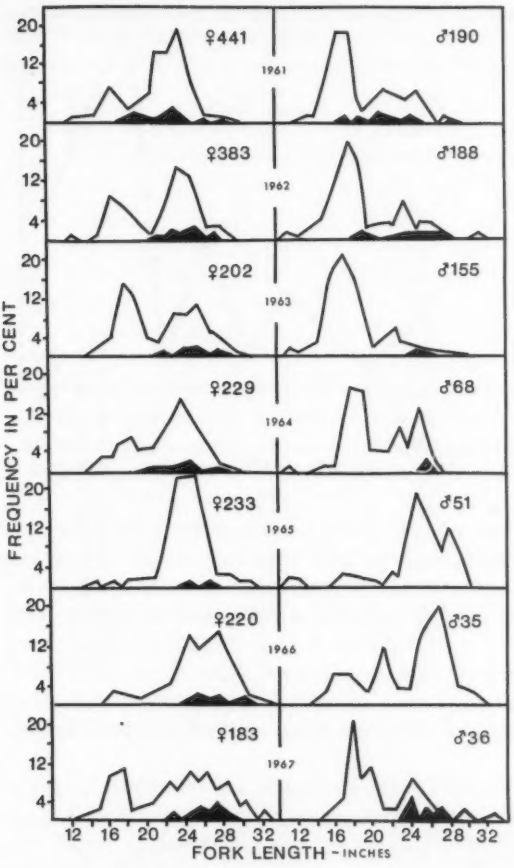

FIG. 2. Length frequency distributions of female and male rainbow trout marked by lampreys (solid polygons) and of unmarked fish (open polygons) during 1961–67.

Table II. The incidence of lamprey marking generally increased from 0 for fish less than 17 inches (432 mm) to 18.8% of the fish in the 30-inch (762-mm) length class. Also, the mean numbers of lamprey marks per fish generally increased with increase in body length.

Multiple marking was found on 56 (30%) of the 185 rainbow trout which bore evidence of lamprey attack. The frequency of marks for rainbow trout of both sexes was as follows: 0 marks — 2429 fish; 1 — 129; 2 — 45; 3 — 8; 4 — 3.

The locations of lamprey marks are shown in Fig. 3. No marks were observed on the head. The greatest numbers of marks were noted in regions

TABLE II. Frequencies of lamprey marks on rainbow trout of various lengths from the spawning population of the Nottawasaga River 1961–67.

Length class (*inches*)	No. of trout examined	No. of trout with marks	Per cent with marks	Avg no of marks per fish
10.0–10.9	3	–	–	–
11.0–11.9	4	–	–	–
12.0–12.9	6	–	–	–
13.0–13.9	10	–	–	–
14.0–14.9	26	–	–	–
15.0–15.9	81	–	–	–
16.0–16.9	207	–	–	–
17.0–17.9	242	1	0.4	1.0
18.0–18.9	169	1	0.6	1.0
19.0–19.9	102	4	3.9	1.3
20.0–20.9	100	8	8.0	1.0
21.0–21.9	174	12	6.9	1.3
22.0–22.9	246	17	6.9	1.5
23.0–23.9	328	26	7.9	1.6
24.0–24.9	305	32	10.5	1.4
25.0–25.9	249	37	14.9	1.4
26.0–26.9	142	14	9.9	1.5
27.0–27.9	110	20	18.2	1.7
28.0–28.9	71	8	11.3	1.9
29.0–29.9	19	2	10.5	1.5
30.0–30.9	16	3	18.8	1.0
31.0–31.9	2	–	–	–
32.0–32.9	2	–	–	–

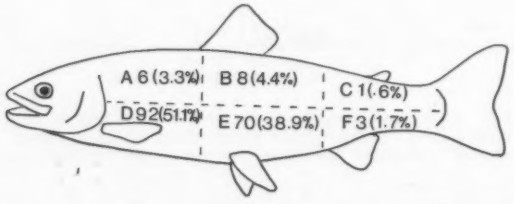

FIG. 3. Diagram of rainbow trout showing locations of lamprey marks for 1962–67. Numbers of marks and percentages of total marks are indicated for each region.

D and E, below the lateral line. These findings are similar to those of Davis (1967) for the locations of lamprey marks on landlocked salmon, *Salmo salar*.

The incidence of lamprey marks (Fig. 4) reached a maximum of 17.2% in the spring of 1962, then declined abruptly to 1.3% in the fall of the same year. From the fall of 1962 to the spring of 1966 the percentage of marked fish fluctuated between 1.3% and 7%; then it increased to 10.5% in the spring of 1967.

FIG. 4. The incidence of lamprey marks on 2614 aduit rainbow trout from the Nottawasaga River, 1961–67 (S, spring; F, fall).

The numbers of rainbow trout which passed through the fishway ranged from a maximum of 578 in the spring of 1961 to a minimum of 200 in the spring of 1963. Female rainbow trout greatly outnumbered the males in the spawning migration each year from 1961 to 1966 inclusive. The ratios of males to females declined from 1:2 in 1961 to 1:6 in 1966.

Of the 2614 rainbow trout which were tagged and released at the fishway during the study, 214 were recaptured in the Nottawasaga River system and in the shoal waters of Georgian Bay within 28 miles (45 km) of the river mouth (Fig. 1).

During the entire study, no sea lampreys were observed to be attached to rainbow trout in the fishway, and there was no evidence that sea lampreys attacked rainbow trout while in the Nottawasaga River (F. H. Marshall, personal communication).

SUMMARY AND DISCUSSION

Although we have no estimate of trout mortality attributable to lamprey parasitism, the incidence of lamprey marking (7.1% of the trout examined) suggests that the parasitism on rainbow trout in Georgian Bay is substantial. However, a considerable proportion of the trout survived lamprey parasitism. This is indicated by the large numbers of fish bearing evidence of from 1 to 4 attacks.

The percentage of rainbow trout possessing lamprey marks increased with fish size. However, lamprey marks were only found on fish over 16 inches (40 cm) in length. These observations are similar to those of Hartman (1959) for lamprey parasitism of rainbow trout in Seneca Lake.

The observations in the present study also compare with those of other authors for lamprey parasitism of lake trout. Wigley (MS, 1953) reported on

lamprey parasitism on lake trout in Cayuga Lake. He found that both the number of trout attacked and the number of scars per fish increased with fish size. Wigley concluded that two factors were responsible: (1) parasite preference for large trout; (2) high mortality among small lake trout attacked by lampreys. Budd and Fry (1960) reported that the incidence of lamprey scarring of lake trout in South Bay, Lake Huron under 17 inches fork length was 3% as compared with 63% for fish in the 20–22-inch class. Pycha et al. (1965) stated that hatchery-reared (yearling) lake trout appeared to be immune to lamprey attack for the first 2–3 years after release in Lake Superior.

The initial migrations of the majority of the rainbow trout from the Nottawasaga River to Georgian Bay occur in the 2nd or 3rd year of life (Wainio, 1962). Lamprey parasitism likely begins when the lake-ward bound rainbow trout and the metamorphosed lampreys share the environment of the river mouth or Georgian Bay for the first time. Evidence is accumulating which suggests that sea lampreys tend to remain near the stream where they hatch (Fisheries Research Board of Canada, 1963, p. 70). Recapture data from tagged rainbow trout in the present study indicate that the Nottawasaga River rainbow trout inhabit a relatively small portion of Georgian Bay, in the general vicinity of the river mouth (Fig. 1). It is likely, therefore, that the majority of lamprey attacks on this population are by lampreys which are native to the same or adjacent rivers.

Cucin and Regier (1965) noted that the percentage of the total annual catch of lake whitefish, *Coregonus clupeaformis* (Mitchill), in southern Georgian Bay bearing fresh lamprey wounds fell from 3.7 to 0.8 from 1960 to 1962 inclusive. Wainio (MS, 1966) reported a decrease in the percentage of marked northern pike, *Esox lucius* Linnaeus, captured from the same waters, from 10.5 to 2.5 from 1961 to 1963 inclusive. The present study (Fig. 4) shows a peak incidence of marking of 17.2% for rainbow trout in the spring of 1962, and a decline to 1.3% in the fall of the same year. The percentage of fish marked fluctuated at a relatively low level from the fall of 1962 for the next 4 years. These observations suggest a considerable reduction in lamprey activity in southern Georgian Bay in the years after the chemical treatment of lamprey spawning streams. The difference between the time of the onset of the reduction in lamprey marking of the Nottawasaga rainbow trout and those of the reductions in the whitefish and northern pike populations may be partly a result of the fact that the Nottawasaga lamprey population was treated with lampricide approximately 1 year later than that of the other lamprey spawning streams of southern Georgian Bay.

The low level of lamprey wounding of rainbow trout from the fall of 1962 to the spring of 1966 inclusive indicates a lack of any substantial recruitment to the adult lamprey population of southern Georgian Bay from the Nottawasaga River from the time of the lampricide treatment in 1961 to the spring of 1966. These observations are in agreement with those of Smith (1967), who found a 5-year minimum duration of larval life in an experimentally introduced lamprey population in the Big Garlic River of Lake Superior. The

moderate increase in the incidence of marking of Nottawasaga rainbow trout which occurred in 1967 (Fig. 4) suggests that a substantial number of larval sea lamprey had metamorphosed to the adult (parasitic) stage.

The mean ratio of male to female rainbow trout in this study was 0.38:1. This ratio compares with 0.84:1 in a spawning population of rainbow trout in a tributary in the Finger Lakes (Hartman, 1959). The lower percentage of marked male than female rainbow trout (Fig. 2, Table I) is in agreement with Hartman's data. However, the general incidence of lamprey marking on the Finger Lakes population was heavier than in the present study. The lower male to female ratio of the Nottawasaga trout may be partly explained by a heavier exploitation rate for male fish. Recaptures of tagged male and female rainbow trout indicated a capture rate of approximately 10.7% for males, compared with approximately 7.2% for females.

The downward trend in the annual numbers of rainbow trout passing through the fishway is not necessarily indicative of population decline in rainbow trout, because the efficiency of operation of the fishway was related to available manpower and varied from year to year. Also, it was occasionally possible for rainbow trout to ascend a side dam near the fishway during periods of freshets.

It was assumed that no significant mortality of rainbow trout occurred in the Nottawasaga River as a result of the lampricide treatment in 1961. This assumption is based on observations made during and after the treatment and on results of detailed studies (A. Lamsa and A. A. Wainio, unpublished data) on trout survival in Silver Creek of Georgian Bay made before and after lampricide treatment.

That the Nottawasaga rainbow trout benefited from the partial control of lampreys in 1960 and 1961 is suggested by the gradual shift in the mean of the length distribution curves (Fig. 2) to higher size and age classes.

ACKNOWLEDGMENTS

The authors are indebted to Conservation Officer R. Toth, Mr Wm. Moir, and especially Conservation Officer F. H. Marshall for the operation of the fishway and the collection of field data.

Dr J. J. Tibbles and Mr A. Lamsa of the Department of Fisheries of Canada provided background information on sea lampreys in Lake Huron. Thanks are extended to Dr A. McCombie and Mr K. H. Loftus of the Ontario Department of Lands and Forests and Dr L. Butler of the University of Toronto for the critical reading of the manuscript.

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The Ultrastructure of the White Striated Myotomal Muscle of the Cod, *Gadus morhua*[1,2]

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ABSTRACT

The structure of the white skeletal muscle of the cod (*Gadus morhua*) is described. The peripheral fibrils are ribbon-like and rectangular in cross section with the long axis normal to the sarcolemma. The inner fibrils are mainly polygonal in cross section. Most of the mitochondria and nuclei are peripheral to the fibrils and next to the sarcolemma. The arrangement of the contractile proteins is typical for striated muscle, and the sarcoplasmic reticulum and transverse tubular system are similar to those in other white skeletal fish muscle. A distinct N-band is apparent with indications of branching and reorientation of the actin filaments. Mitochondria are often closely associated with the Z line.

INTRODUCTION

Although there is close resemblance in the structure of the skeletal muscle in various vertebrates, there are differences in the arrangement of the fibrils, the amount of sarcoplasm, the relationships of the nuclei and mitochondria to other muscle components, and the arrangement of the sarcoplasmic reticulum. Attempts have been made to associate many of these differences with the differences in colour and speed of muscles, but the correlation is not complete (Bourne, 1960). White muscle usually has less sarcoplasm containing less glycogen and fewer mitochondria than red muscle, which often contracts and fatigues more slowly than white muscle. This difference has been shown in *Mollienesia* (Franzini-Armstrong and Porter, 1964), *Perca* (Kilarski, 1965), and *Esox* (Kilarski, 1966). Fish white skeletal fibres are often larger than red skeletal fibres, and generally have a central mass of fibrils which are polyhedral in cross-section, whereas those at the periphery are rectangular with the long axis normal to the sarcolemma.

The fast-acting muscles of the garter snake, *Thamnophis sirtalis* (Hess, 1965) and *Rana temporaria* (Page, 1965) possess a well-defined transverse tubular system, at the A–I junctions in the snake and at the Z band in the frog, whereas slower muscles possess only a few transverse tubules or none at all. There appears to be no correlation between the speed of the muscle and the development of the transverse tubular system in fish. Numerous fish muscles so far described appear to have triads at the Z line, for instance the white truncal and red subcutaneous muscles of *Perca* (Kilarski, 1966), the

[1]Received for publication February 6, 1967.

[2]This work was carried out by the first author in partial fulfillment of the requirements for the degree of Master of Science in the Department of Biology at Dalhousie University, Halifax, N.S.

J. Fish. Res. Bd. Canada, 24(12), 1967.
Printed in Canada.

red and white truncal muscles of *Mollienesia* (Franzini-Armstrong and Porter, 1964), the red levator pinnae pectoralis and white flexor pinnae pectoralis muscles of *Ophiocephalus* (Nakajima, 1962), and the pectoral fin muscle of *Clinocottus* (Peachey, 1966). However, the eyeball muscles of *Perca* contain fine red fibres, rich in glycogen, with triads at the A–I junctions, and wider fibres containing less glycogen with triads at the Z band. Triads at the A–I junctions also occur in the eyeball muscles of *Esox* and *Fundulus* (Reger, 1961), the fast-acting swim-bladder muscles of *Opsanus* (Fawcett and Revel, 1961), and the slow-acting swim-bladder muscle of *Lota* (Kilarski, 1964).

We describe the fine structure of cod white truncal muscle, both for the purpose of comparison with the muscle of the foregoing fish, and to provide a basis of comparison when studying ultrastructural changes in the fillet associated with processing and storage effects.

METHODS

Cod 50–60 cm long were held alive in the seawater tanks at the Halifax Laboratory until they were needed for experimental purposes. They were anaesthetized with tricaine methanesulphonate, and taken to a cold room at 4 C. All the following operations were carried out in the cold room until the stage of dehydration in 90% acetone was reached, when the sample was allowed to come to room temperature. Small pieces of white myotomal muscle were excised from the dorsolateral part of the fish at the region where the body is deepest. The muscle was cut into smaller fragments in 2% glutaraldehyde buffered with 0.2 M phosphate buffer at *p*H 7.2, then fixed in the buffered glutaraldehyde for 8 hr. The tissues were washed in phosphate buffer and fixed in buffered 2% osmium tetroxide for 1½ hr. After a brief rinse in distilled water they were dehydrated in acetone, embedded in Araldite, and cured for 3 days at 60 C. Silver and gray sections were cut with an LKB Ultratome, and picked up on unsupported grids, or grids with a carbon-stabilized formvar coat. The sections were double-stained with saturated aqueous uranyl acetate or 25% uranyl acetate in absolute methanol, followed by Millonig's lead hydroxide. Sections on coated grids stained with alcoholic uranyl acetate gave the clearest results. The sections were studied and photographed with an Hitachi HS7S electron microscope.

OBSERVATIONS

In cross section the fibre consists of rectangular outer fibrils, their length normal to the sarcolemma, surrounding smaller inner fibrils of irregular shape (Fig. 1). Most nuclei and mitochondria are near the sarcolemma (Fig. 2), but are occasionally seen in extensions of the sarcoplasm into the fibre.

The sarcomeres are similar to those of other vertebrates (Fig. 2 and 3). The A zone is 1.3 μ long. The arrangement of the filaments in longitudinal and transverse section (Fig. 4 and 5) resembles that described by Huxley in rabbit skeletal muscle (1957). The actin filaments show an orderly tetragonal arrangement with cross connections at the Z band (Fig. 6) which has also

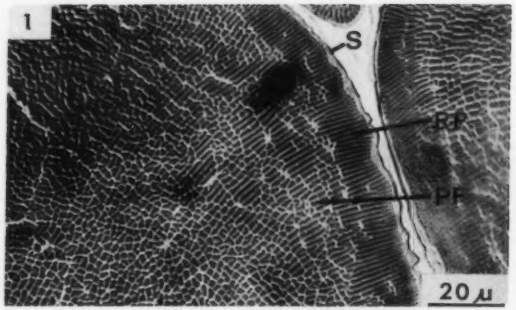

FIG. 1. Phase light micrograph of approximately ½ μ section of T.S. cod white skeletal muscle fibre fixed and embedded as for electron microscopy, stained in Mallory's Azure 11-methylene blue (Richardson et al., Stain Technology 6, p. 313, 1960).

ABBREVIATIONS: A, A zone; Ac, actin; BM, basement membrane; C, concentration of cisternae of sarcoplasmic reticulum opposite M zone; CM, cell membrane; CN, convoluted nuclear substance; DI, deep invagination of the sarcolemma; H, H band; I, I zone; L, large vesicle of the sarcoplasmic reticulum; M, M zone; Mi, mitochondrion; My, myosin; N, nucleus; NB, N band; NP, nuclear pore; PF, polygonal fibrils in centre of fibre; RC, reticulin and collagen fibrils; RF, ribbon-like fibrils at periphery of fibre; S, sarcolemma; SI, shallow invagination of sarcolemma; SR, sarcoplasmic reticulum; T, transverse tubule; Tr, triad; Z, Z line.

FIG. 2. Transverse section at the region of junction of two fibres. The sarcolemmas and underlying sarcoplasm containing mitochondria and nuclei are shown, and the peripheral radial fibrils whose constituent myofilaments vary in appearance as the section passes through the I, A, and H zones.

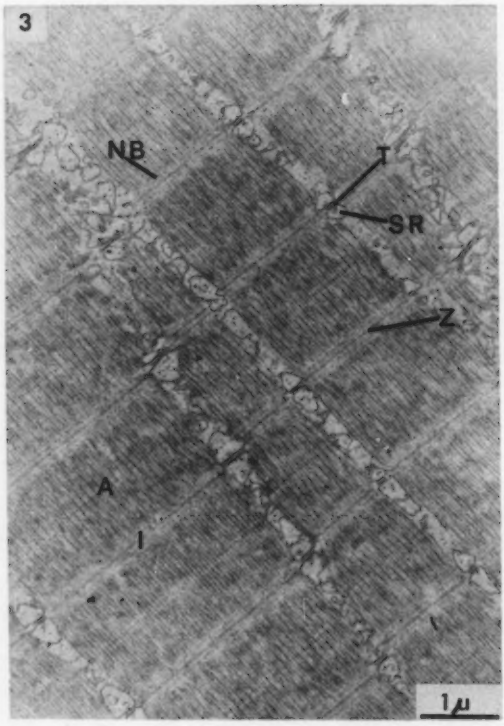

FIG. 3. 'Longitudinal section showing the arrangement of myofilaments, transverse tubular system, and sarcoplasmic reticulum.

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FIG. 4. Longitudinal section of one sarcomere showing the arrangement of myosin and actin filaments and their lateral extensions. These extensions are well developed in the myosin in the centre of the H zone, giving the appearance of the M band.

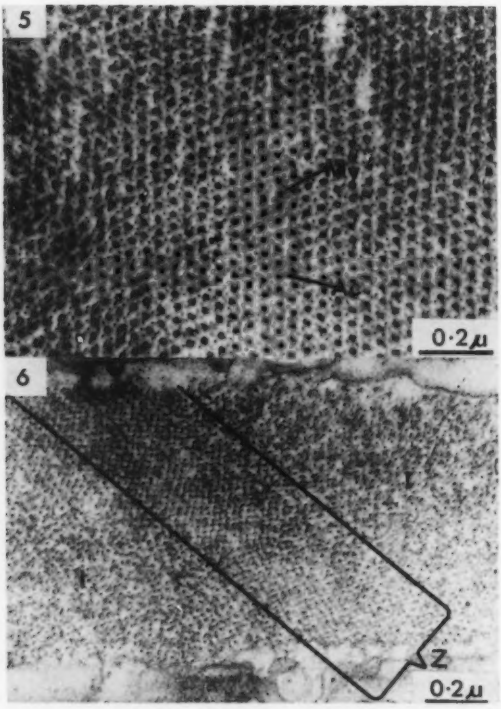

FIG. 5. Transverse section. The actin filaments are placed hexagonally round each myosin filament.

FIG. 6. Transverse section of the I zone region. The tetragonal arrangement of the filaments in the Z band and connections between them can be seen. At either side of the Z band the cross-connections are no longer apparent and the actin filaments are disoriented.

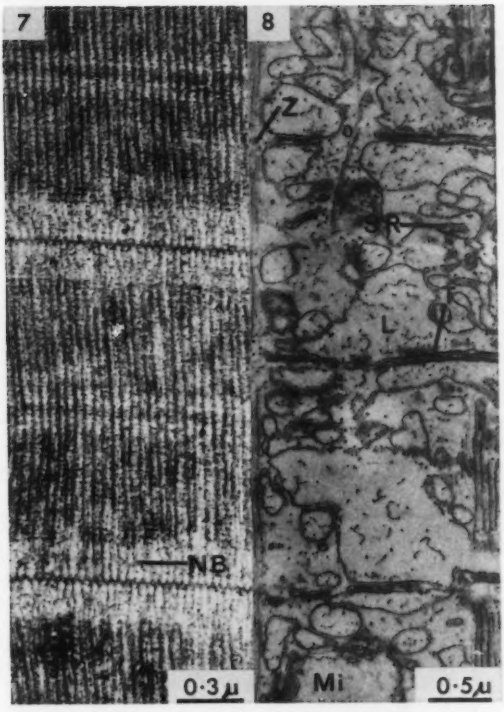

FIG. 7. Longitudinal section. The actin filaments show signs of branching in the N band.

FIG. 8. Longitudinal section. Large vesicles of the sarcoplasmic reticulum lie close to the transverse tubules at the Z line, forming triads, and irregular cisternae connect the enlarged vesicles.

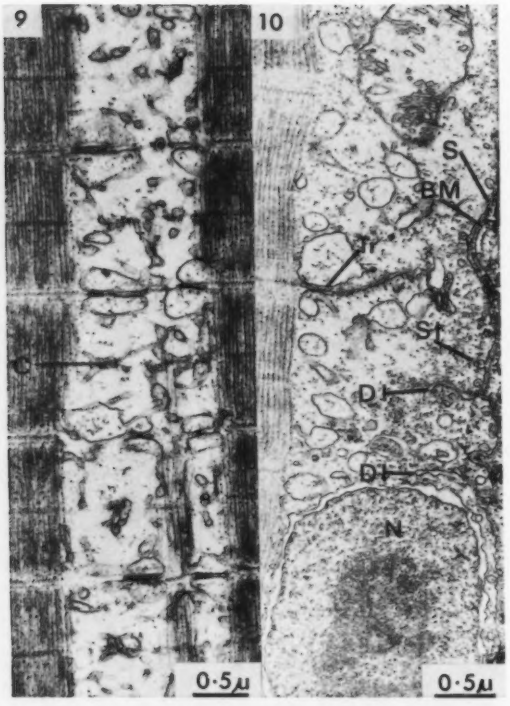

FIG. 9. Longitudinal section. There is no definite arrangement of the sarcoplasmic reticulum opposite the M zone but there is some concentration of transversely oriented cisternae in this region.

FIG. 10. Longitudinal section. The sarcolemma consists of a cell and basement membrane, and has deep and shallow invaginations which usually only involve the cell membrane. A transverse tubule extends from a triad towards the sarcolemma.

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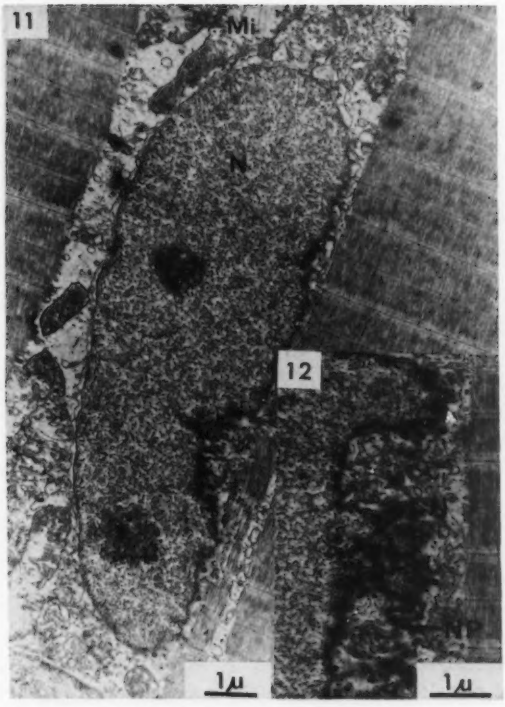

FIG. 11. Longitudinal section showing the typical appearance of the nucleus and mitochondria.

FIG. 12. Longitudinal section. The section has been cut at a tangent to the nuclear surface. The nuclear pores and convoluted arrangement of the substance in the nucleus just under the nuclear membrane are evident.

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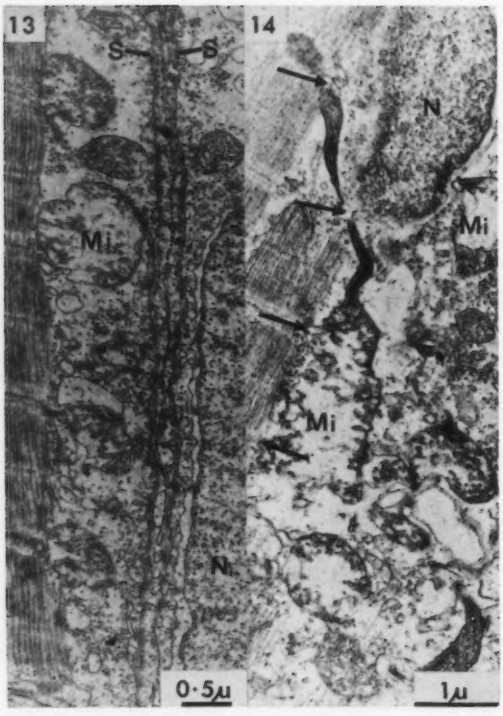

FIG. 13. Longitudinal section. The close association often found between mitochondria and the Z line is shown.

FIG. 14. One mitochondrion has close associations with several I zones (arrows). Another shows a close association with the nucleus.

been described in frog skeletal muscle by Knappeis and Carlsen (1962). The most distinctive feature is a fairly clear N-band, which shows as a dark region in the I band about half-way between the Z line and the A band (Fig. 7). A different number of actin filaments is often visible on either side of the band, which appears to be a region of well-developed cross connections or branching between the filaments. This is most clearly shown where the plane of sectioning results in a distinct Z line.

Transverse tubules occur at the Z line, and on either side of them are large vesicles of the sarcoplasmic reticulum connected by ramifying cisternae (Fig. 8). In cross section the sarcoplasmic reticulum usually consists of single rows of vesicles between the fibrils, which are less broken up in the region of the large vesicles opposite the I zone than opposite the A zone (Fig. 2). Sometimes there is an indication of a concentration of cisternae in the region of the M zone (Fig. 9). At the triads there is an accumulation of material in the sarcoplasmic reticulum, in the transverse tubule, and in the space between their membranes (Fig. 8). Chains of particles which are round and fairly uniform in size and density occur in the sarcoplasmic reticulum. These particles are easily distinguished from the fine filamentous material in the mitochondria, and from the particles in the sarcoplasm outside the sarcoplasmic reticulum, which are less dense and more unequal in size.

The sarcolemma shows the typical arrangement of a cell membrane and basement membrane (Fig. 10). Outside it are collagen and reticulin fibres which form a network between two opposing sarcolemmas (Fig. 2). There are shallow and deep invaginations of the sarcolemma, which usually only involve the cell membrane.

The nuclei and mitochondria have a typical structure (Fig. 11). The pores of a nucleus are shown in surface view in Fig. 12. There appears to be a convoluted arrangement of the nuclear material just inside the nuclear membrane. Some mitochondria have orderly, closely packed cristae whereas others are distended. The cristae often appear round suggesting that they are tubular. Frequently mitochondria are closely associated with the Z line (Fig. 13) and one mitochondrion may be closely related to the Z band of several sarcomeres (Fig. 14). There are also sometimes close associations between mitochondria and nuclei (Fig. 11 and 14).

DISCUSSION

Love (1958) found cod myotomal muscle fibres up to 300 μ wide in a 93-cm cod, which is much larger than those of the myotomal muscles of *Ophiocephalus* (30–80 μ; Nakajima, 1962) or *Perca* (27–63 μ; Kilarski, 1965). However, much of the microanatomy of the cod muscle is typical of fish white myotomal muscle, such as the arrangement of fibrils in the fibre, the restriction of mitochondria and nuclei mainly to the narrow peripheral zone of sarcoplasm, and the presence of triads only at the Z line. The micrographs presented in this account do not show a complete continuity of the transverse tubular

system with the sarcolemma, although this would be expected from its occurrence in other animals such as other fish (Franzini-Armstrong and Porter, 1964) amphibians (Page, 1965), reptiles (Hess, 1965), and mammals (Walker and Randolph, 1965). However, transverse tubules can often be seen extending into the sarcoplasm towards the sarcolemma (Fig. 10); and the deep invaginations described above may be transverse tubules joining the sarcolemma.

The transverse tubules are believed to provide the means of transmission of cell membrane depolarizations caused by electrical stimuli to the interior of the cell. The triad is probably the site where this depolarization initiates release of calcium from the sarcoplasmic reticulum, which in turn may activate the myofibrillar ATPase and cause contraction (Philpott and Goldstein, 1967). The close association of the mitochondria as well as triads with the Z line suggests that they may produce material essential in this sequence of events. Since mitochondria are usually the main source of ATP in a cell (Lehninger, 1964) their main function may be to regenerate ATP from the ADP produced by the myofibrillar ATPase. ATP is also probably required for calcium accumulation in the sarcoplasmic reticulum during relaxation of the muscle (Gergely, 1964). Calcium has been located in the terminal sacs of the sarcoplasmic reticulum (Constantin et al., 1965), and the particles which are concentrated in this region in Fig. 8 may represent sites of calcium accumulation. The fairly uniform size and density of these particles suggests they could also be ribosomes. Muscatello et al. (1961) describe a sarcotubular fraction with particles which contain RNA and incorporate amino acids; however, these particles are 150 A° in diameter, the average size for ribosomes, whereas the particles in cod sarcoplasmic reticulum are smaller and denser.

According to Fawcett (1966) and Bourne (1960) flask-shaped invaginations of the sarcolemma of the type found in cod skeletal muscle commonly occur at the surface of many types of cells, including smooth and striated muscle fibres. Their regular occurrence in endothelial cells leads to the suggestion that they may be involved in the transport of materials across the capillary wall, and they may also have a transport function in muscle cells.

The N band has been described above as a region of well-developed cross connections or branching. Knappeis and Carlsen (1962) suggest that actin is arranged in a tetragonal fashion at the Z band, but in a hexagonal fashion in the A zone. The N band is a region where the reorientation of the actin filaments from the tetragonal to the hexagonal arrangement could take place.

ACKNOWLEDGMENT

We gratefully acknowledge the assistance of Dr Cameron of Dalhousie University, Halifax, N.S., who read the manuscript and offered valuable advice.

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Phospholipase A Activity in Rainbow Trout Muscle[1]

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ABSTRACT

A sensitive method for assay of phospholipase A activity in the lateral line muscle of rainbow trout is described. ^{14}C labelled lecithin was converted to lysolecithin by the enzyme. Unreacted lecithin was removed by silicic acid column chromatography and the lysolecithin recovered by thin-layer chromatography. The amount of lysolecithin formed was between 43 and 87 mμmoles per gram lateral line muscle per hour under the experimental conditions. The amount formed was directly proportional to time between half an hour and 4 hr and the optimum *p*H was found to be approximately 7.5. The results are discussed in relation to the enzymic activity previously demonstrated in fish muscle.

INTRODUCTION

In the previous investigations on the enzymic hydrolysis of lecithin in rainbow trout muscle it was shown that deacylation of lecithin to glycerylphosphorylcholine (GPC) is the main catabolic pathway (Bilinski and Jonas, 1966a, b). In agreement with such an enzymic activity it was also found that cold storage of rainbow trout muscle gave rise to formation of GPC and free fatty acids (Jonas and Bilinski, 1967). In a mechanism involving two enzymes in the formation of GPC, lysolecithin, formed from lecithin by the action of phospholipase A, is deacylated to GPC under the action of lysolecithinase. The presence of lysolecithinase is well established in fish muscle (Yurkowski and Brockerhoff, 1965; Bilinski and Jonas, 1966a; Cohen et al., 1967) but evidence for the occurrence of phospholipase A is lacking. The present work was therefore initiated to attempt to establish this missing link. The method followed to demonstrate the presence of phospholipase A in fish muscle is a modification of the radioactive tracer procedure employed previously (Bilinski and Jonas, 1966a). Lecithin labelled with choline-methyl-^{14}C, prepared biosynthetically from fish was incubated with preparations from rainbow trout lateral line muscle and the formation of lysolecithin ^{14}C was determined after its isolation by thin-layer chromatography.

MATERIALS AND METHODS

Fish

Two-year-old rainbow trout (*Salmo gairdneri*) obtained from a commercial hatchery and held in a freshwater aquarium at this laboratory were used in these experiments.

[1]Received for publication July 5, 1967.

J. Fish. Res. Bd. Canada, 24(12), 1967.
Printed in Canada.

Tissue Preparations

Lateral line muscle homogenates were prepared as previously described (Bilinski and Jonas, 1966a). For the determination of the subcellular distribution of the enzyme activity, homogenates prepared in 8.5% sucrose were fractionated by differential centrifugation (Bilinski and Jonas, 1966b). The protein content of the fractions was determined by microkjeldahl method (Steyermark, 1951).

Preparation of Labelled Lecithin-^{14}C

^{14}C labelled phospholipids were prepared from rainbow trout (Bilinski and Jonas, 1966a), using choline–methyl–^{14}C–chloride (New England Corp.). Pure ^{14}C labelled lecithin was prepared from the above phospholipid by the procedure described by Saito and Hanahan (1962), involving the use of aluminum oxide and silicic acid chromatography. Its purity was confirmed by thin-layer chromatography (Mangold, 1961). It had the following composition: 3.5% P; 13.5% choline; 17,500 cpm per milligram.

Incubation Procedure

The incubation medium used for the assay included calcium as a phospholipase A activator and deoxycholate as a lysolecithinase inhibitor (Bilinski and Jonas, 1966a). Of the various buffers generally used in the measurement of phospholipase A activity (Magee and Thompson, 1960; Olley, 1961; Doizaki and Zieve, 1964), Tris buffer was found to give the best rate of enzyme activity with minimum interference in the subsequent assay procedure.

Unless otherwise stated, the reaction mixture consisted of 1 mg ^{14}C labelled lecithin; 10 mg deoxycholate; 2 μmoles calcium chloride; 60 μmoles Tris buffer *p*H 7.5; and 300 mg of lateral line muscle in a total volume of 3.0 ml. The air in the tube was replaced by nitrogen (Webster and Thompson, 1965) and the tube covered with parafilm and incubated in a water bath at 35 C with continuous shaking for 4 hr.

Isolation and Measurement of Lysolecithin

The lipids were extracted by shaking the incubation mixture with 4 volumes of 2:1 v/v chloroform methanol mixture (Webster and Thompson, 1965). The chloroform layer was separated, dried in a rotary flash evaporator, and the unreacted lecithin removed by silicic acid chromatography. Silicic acid (5 g) (Mallinkrodt analytical reagent 100 mesh) was activated by keeping it at 120 C overnight. Chloroform methanol mixture (9:1 v/v) was added to make it into a slurry and poured into a column (2 × 30 cm). The dry lipid residue was dissolved in 5.0 ml of the same chloroform methanol mixture and poured on the silicic acid column and washed with 45 ml of the same mixture. The lecithin was removed by elution with 250 ml 3:2 v/v chloroform methanol mixture. The lysolecithin was eluted with 50 ml 96:4 v/v methanol water mixture (Webster and Thompson, 1962). Elution rate was approximately

60 ml per hour. The lysolecithin eluate was dried in a rotary flash evaporator, redissolved in a small volume of methanol and concentrated to approximately 0.5 ml and subjected to thin-layer chromatography.

Eastman chromagram silica gel sheet (Distillation Products Industries, Rochester, New York), type K301R2 was found to be satisfactory for this separation. The sheet was dried before use in an oven for approximately 2 hr at 100 C. The lysolecithin concentrate in methanol and standard non-radioactive fish lecithin and lysolecithin were spotted on the same sheet to confirm the separation between the two compounds. The sheet was dried at laboratory temperature and developed in a Desaga rectangular developing chamber using 100 ml of 65:25:4 v/v chloroform–methanol–water mixture (Mangold, 1961). Complete saturation of the chamber with solvent vapour was essential to obtain good separation. This was accomplished by lining the walls of the jar with filter paper. The developed chromogram sheet was air dried and the zones visualized by keeping it in a jar of iodine vapour for a few minutes.

The distribution of radioactivity in the R_F zones of lysolecithin and those located immediately below and above were determined as follows. The silica gel corresponding to each zone was scraped into centrifuge tubes. This was extracted with methanol and centrifuged; the methanol extract was dried in cupped aluminum pans and its radioactivity counted with a Nuclear Chicago gas flow counter (Bilinski and Jonas, 1966a). According to this method, the radioactivity was found only in the lysolecithin zone.

RESULTS

Lateral line muscle of rainbow trout assayed for phospholipase A activity by the method described above, hydrolysed lecithin releasing lysolecithin which amounted to an average of 67 ± 14.2 (6)[2] mμmoles per gram muscle per hour. When several experiments were performed using boiled (5 min *p*H 7.5) preparations of the same muscle, no lysolecithin could be detected, showing that the activity obtained was due to the active enzymes present in the muscle. When the incubation time was reduced, the activity obtained was also reduced proportionately (Fig. 2), showing a linear relationship between time and enzyme activity between half an hour and 4 hr. As shown in Fig. 1, a *p*H close to 7.5 seemed to be optimum for phospholipase A activity in the muscle. The distribution of phospholipase A activity was determined in subcellular fractions from lateral line muscle. As shown in Table I, a 3-fold higher specific activity was obtained in the microsome fraction of the lateral line muscle as compared with the activity of the total homogenate, the mitochondria having an intermediate level of activity.

DISCUSSION

The results indicating the enzymic conversion of lecithin to lysolecithin in rainbow trout lateral line muscle provide the first support for the presence

[2]Mean value and standard deviation. The number of experiments is indicated in parentheses.

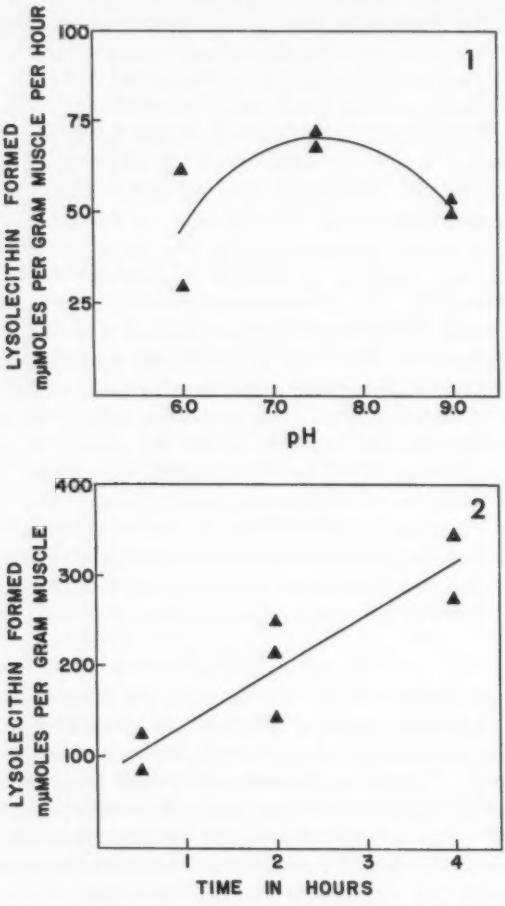

FIG. 1. Effect of *p*H on phospholipase A activity in the lateral line muscle.

FIG. 2. Effect of incubation time on phospholipase A activity in the lateral line muscle.

of phospholipase A in fish muscle. Complete deacylation of lecithin to GPC was shown to take place in trout muscle (Bilinski and Jonas, 1966a) and it appears in view of the present results that fish muscle has the necessary enzymes (phospholipase A and lysolecithinase) which may bring this conversion in a two-step reaction. The possibility that lecithin may also be converted to GPC by the action of a single enzyme (diacylhydrolase or phospholipase B) cannot be discounted. This problem has not yet been resolved in case of other biological systems (van Deenen, 1964; Dawson, 1966; Baer and Kates, 1967).

TABLE I. Distribution of phospholipase A activity in different fractions of the lateral line muscle of rainbow trout (*Salmo gairdneri*).

Centrifugal fractionation	Homogenate fraction	Specific activity[a]	
20% muscle homogenate in 8.5% sucrose	Total homogenate	1.0	
600 *g*, 10 min			
supernate			
10,000 *g*, 10 min			
sediment	Mitochondria	1.36 1.53 1.34	1.41
supernate			
50,000 *g*, 60 min			
sediment	Microsome	3.48 3.51 3.12	3.37

[a]Specific activity, i.e. activity per mg protein N, is expressed in terms of total homogenate which is taken as equal to 1.

Investigations, including purification of the enzymes involved, are necessary to elucidate this problem.

Phospholipase A, also denoted as phosphatidyl acyl hydrolase (EC 3.1.1.4) is widely distributed in nature. This enzyme is present at a very high concentration in snake venoms and as a digestive enzyme in the mammalian pancreas. At a considerably lower level of activity, phospholipase A was recently demonstrated to be present in various animal tissues (Gallai-Hatchard and Thompson, 1965; Rossi et al., 1965; Scherphof and van Deenen, 1965; Bjørnstad, 1966a, b). The fully characterized phospholipase A has been obtained only from sources in which it is present at high concentration (van Deenen, 1964) but indications are that this enzyme differs in general properties and mode of action from phospholipase A found in mammalian tissues. Phospholipase A from snake venom catalyzed the hydrolysis of the β-ester linkage only of lecithin, but this specific mode of action does not apply to phospholipase(s)

A found in animal tissues (Lloveras et al., 1963; van Den Bosch and van Deenen, 1964; Waite and van Deenen, 1967). Though *p*H optimum for venoms and some animal tissues vary from 6.5 to 10.0 (Condrea and De Vries, 1965) the observed optimum of approximately 7.5 is consistent with the observations of Gallai-Hatchard and Thompson (1965), Scherphof and van Deenen (1965), and our own previous observations for the hydrolysis of lecithin to GPC in trout muscle (Bilinski and Jonas, 1966a). The few properties determined for phospholipase A from trout muscle are similar to what has been found for lecithinase (formation of GPC from lecithin) and lysolecithinase (formation of GPC from lysolecithin) in this tissue (Bilinski and Jonas, 1966a). Since lecithinase activity may be made up of phospholipase A and lysolecithinase, the similarity in their general trend of activity could be expected. It has previously been found that the enzymic activity resulting in the formation of GPC from lecithin occurs in various subcellular fractions of rainbow trout lateral line muscle, with the highest concentration in a particulate material exhibiting sedimentation characteristics of microsomes (Bilinski and Jonas, 1966b). The subcellular distribution of phospholipase A was found to be similar, although the difference between the activity of mitochondria and microsomes was less pronounced. In rat liver also phospholipase A does not appear to be confined to one subcellular constituent, and occurs in microsomes and mitochondria (Bjørnstad, 1966a; Waite and van Deenen, 1967).

The enzymic degradation of phospholipids is known to occur during cold storage of fish (Dyer and Dingle, 1961; Lovern and Olley, 1962; Bligh and Scott, 1966). Though phospholipase A activity in fish muscle has been considered by us in connection with the enzymic breakdown of phospholipids, it may also have a function in metabolic transformations of phospholipids other than purely catabolic. The physiological significance of the presence of phospholipase A in animal tissue has been related to the mechanism of phospholipid turnover. A cycle of acyl transfer, involving transacylases and phospholipase A, has been proposed, by which phospholipids with specific fatty acid distribution at α and β position are formed (van Deenen, 1964; van Den Bosch and van Deenen, 1965).

The measurement of phospholipase A in the muscle is rendered difficult by the very low level of activity in this tissue and also because of a possible interference from several other types of enzymes capable of metabolizing lysolecithin (Erbland and Marinetti, 1965a, b). Our earlier attempt to demonstrate the enzymic formation of lysolecithin in fish muscle, using silicic acid column chromatography failed (Bilinski and Jonas, 1966a). The technique used in the present work for the isolation of lysolecithin has been modified, as thin-layer chromatography was found more reliable than column chromatography for the final isolation of lysolecithin.

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Canadian Marine Oils of Low Iodine Value: Fatty Acid Composition of Oils from Newfoundland Turbot (Greenland Halibut), Certain Atlantic Herring, and a Sablefish[1]

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ABSTRACT

Marine oils with iodine values in the range 83–108 from Newfoundland turbot or Greenland halibut (*Reinhardtius hippoglossoides*), sablefish (*Anoplopoma fimbria*), and certain Atlantic herring (*Clupea harengus*), were examined for fatty acid composition by gas–liquid chromatography. The herring oils differed from the other oils in having high levels of C_{20} and especially C_{22} fatty acids (chiefly monounsaturated). The sablefish oil had a high level of C_{18} fatty acids, the turbot oil a composition intermediate between the herring and sablefish oils. All of these oils contained moderate amounts of polyunsaturated fatty acids (7.3–14.4%). The low iodine values were primarily due to monounsaturated fatty acids and not to saturated fatty acids (17.1–21.0%)

INTRODUCTION

A survey of commercially produced Atlantic herring oils (Ackman and Eaton, 1966) singled out 1 of 12 random samples as having a remarkably low iodine value (I.V.) of 111.6. The normal range of I.V. for commercially produced herring oils is 118–145 (Bailey, 1952; Lambertsen and Braekkan, 1965; Ackman and Eaton, 1966). The unusual oil was produced at Caraquet, New Brunswick, in August 1964. It is not unique as herring oil samples with similar or more extreme characteristics were obtained from the same general area in 1965 and 1966.

Most commercial oils from teleost fish of current interest have I.V. in the range 118–190 (Ackman, 1966). Fatty acid interrelationships in triglyceride oils with iodine values as low as 100 have therefore received little attention. Wider implications of such interrelationships have been sought by examining additional herring oils, three samples of muscle oil from an Atlantic flatfish, *Reinhardtius hippoglossoides*, known as Newfoundland turbot or Greenland halibut, and one sample of muscle oil from the sablefish, *Anoplopoma fimbria*, a Pacific species also known as black cod.

EXPERIMENTAL

Materials and Gas–Liquid Chromatography (GLC)

The herring oil samples, and that of turbot oil sample 3, were obtained from commercial firms and were produced by commercial reduction of whole

[1]Received for publication April 11, 1967.

J. Fish. Res. Bd. Canada, 24(12), 1967.
Printed in Canada.

fish in the case of the herring and of filleting line scrap (heads, bone, skin, and muscle residues) in the case of turbot oil sample 3. Turbot oil samples 1 and 2 were respectively from dressed fish (whole except for viscera) and skinless fillets and were prepared by the method of Bligh and Dyer (1959) in the Department of Fisheries of Canada Laboratory, St. John's, Nfld. The sablefish oil was recovered in Halifax from the dorsal muscle of a commercially caught sablefish shipped frozen from Vancouver, B.C. The oil yield by the method of Bligh and Dyer (1959) was 15.9%. Analytical procedures followed those outlined by Ackman and Eaton (1966) but turbot oil samples 1 and 2 were analysed on open-tubular GLC columns as described by Ackman et al. (1967). Minor components observed in GLC were tentatively identified by plotting and separation factors. Agreement for totalled chain-lengths with analyses of chain lengths in hydrogenated samples was satisfactory for packed column GLC and for the open-tubular analysis of turbot oil 2. Totalled C_{16} was high in the analysis of turbot oil 1 by 6% (relative) and totalled C_{22} low by 14%, whereas totalled C_{18} and C_{20} were accurate to $\pm 2\%$. Except in this case relative accuracy is expected to be better than $\pm 5\%$ for major components, but for very small components overall accuracy may be no better than $\pm 50\%$. Presentation of weight per cent composition data (Tables I and II) to two places of decimals is for comparative purposes only.

RESULTS

The results of analyses of the low I.V. oils (Tables I–III) show that oils of this type from the three species studied have no unusual features when compared with marine oils in general. There is a sharp differentiation of fatty acids among the three respective basic types (saturated, monounsaturated, and polyunsaturated with five and six double bonds), but despite the low I. V. of these oils, saturated fatty acids are not present to any abnormal extent. As previously noted (Ackman and Eaton, 1966), total saturated acids decrease with decreasing I.V. in the herring oils. Total saturates for the flatfish oil (Igarishi et al., 1962) and sablefish oil analysed by Dolev and Olcott (1965) were respectively 20.1 and 24.4%. Total polyunsaturates can be calculated from the oil I.V. with reasonable accuracy by the appropriate formula (Ackman, 1966; Ackman and Eaton, 1966) and are not inconsiderable percentages of the fatty acids (Table III).

The key components primarily responsible for the low I.V. are the monounsaturated fatty acids. The low I.V. herring oils are typical clupeid oils (Lovern, 1938; Lambertsen and Braekkan, 1965) with larger proportions of 22:1 acids than of 20:1 acids. In the other two oils these acids are less abundant components. Accordingly the totals for 16:1 and 18:1 are nearly twice as high as in the herring oils (Table III). The equivalence of the latter acids (Ackman and Eaton, 1966) is suggested by the ratio 16:0/(16:1 + 18:1). Values for this are moderately consistent for herring oils (average of 0.50 for these four oils as against 0.56 in the previous sampling of herring oils by Ackman and Eaton (1966)). The other two oils examined in this study do

TABLE I. Properties and fatty acid percentage compositions of commercial low I.V. whole-body oils from certain Atlantic herring and of a dorsal muscle oil (laboratory extract) from a sablefish.

Sample:	Herring (*Clupea harengus*)[a] 1	2	3	4	Sablefish (*Anoplopoma fimbria*)[b]
Iodine value (Wijs):	101	103	94	108	83
Non-saponifiables (%):	1.11	–	0.97	0.73	1.01
Free fatty acid (%):	1.93	0.56	–	1.74	–
Fatty acid[c]	Fatty acid methyl ester composition %[d]				
	Saturated				
12:0	0.13	0.20	0.16	0.15	0.06
14:0	6.00	6.98	6.27	5.88	6.66
15:0	0.42	0.50	0.35	0.39	0.30
16:0	9.30	10.64	8.94	9.63	11.08
17:0	0.31	0.23	0.38	0.32	1.02
18:0	0.94	0.98	0.96	1.00	1.85
19:0	NSA	NSA	NSA	NSA	NSA
20:0	0.09	NSA	0.09	0.08	0.08
Total	17.2	19.5	17.1	17.4	21.0
	Monounsaturated				
14:1	0.38	0.40	0.31	0.25	0.25
16:1	7.21	8.01	7.32	9.46	6.65
17:1	0.21	0.19	0.18	0.17	0.29
18:1	12.15	10.87	12.23	9.53	29.02
19:1	0.10	0.16	0.07	0.05	0.12
20:1	19.38	18.95	20.49	15.38	18.08
21:1	NSA	NSA	Trace	NSA	NSA
22:1	29.69	28.03	31.60	32.02	14.75
24:1	0.77	0.80	0.75	0.99	2.16
Total	69.9	67.4	72.9	67.8	71.3
	Diunsaturated				
16:2ω7 } 16:2ω4 }	0.74	0.79	0.62	0.79	1.14
18:2ω6	0.85	1.34	0.53	0.63	0.65
20:2ω6	0.12	0.22	0.13	0.10	0.20
Total	1.7	2.3	1.3	1.5	2.0
	Triunsaturated				
16:3ω4	0.65	0.43	0.48	0.50	0.20
18:3ω6	0.14	0.15	0.09	0.10	0.07
18:3ω3	0.38	0.66	0.27	0.29	0.19
20:3ω6	0.19	0.11	0.14	0.17	0.15
Total	1.4	1.3	1.0	1.1	0.6

(*Continued*)

TABLE I. Properties and fatty acid percentage compositions of commercial low I.V. whole-body oils from certain Atlantic herring and of a dorsal muscle oil (laboratory extract) from a sablefish. — (*Concluded*)

Sample:	Herring (*Clupea harengus*)[a] 1	2	3	4	Sablefish (*Anoplopoma fimbria*)[b]
Iodine value (Wijs):	101	103	94	108	83
Non-saponifiables (%):	1.11	–	0.97	0.73	1.01
Free fatty acid (%):	1.93	0.56	–	1.74	–
Fatty acid[c]	Fatty acid methyl ester composition %[d]				
	Tetraunsaturated				
16:4ω1	0.35	0.53	0.47	0.71	0.69
18:4ω3	1.02	1.41	1.03	1.14	0.32
20:4ω6	0.20	0.11	0.13	0.24	0.26
20:4ω3	0.19	0.40	0.20	0.35	0.18
Total	1.8	2.4	1.8	2.4	1.4
	Pentaunsaturated				
20:5ω3	4.44	3.33	2.62	5.93	1.40
21:5ω2?	0.21	0.18	0.15	0.21	0.27
22:5ω6	0.13	0.05	0.09	0.08	0.06
22:5ω3	0.65	0.54	0.59	0.57	0.53
Total	5.4	4.1	3.5	6.8	2.3
	Hexaunsaturated				
22:6ω3	2.07	2.79	1.87	2.56	1.02
Iodine value calc. from GLC	99	96	91	106	81

[a]1 and 2: Magdalen Islands, July 1965 and May 1966; 3 and 4: Caraquet, N.B., July 1965.
[b]Commercial catch, October 1965.
[c]Shorthand notation for chain length:number of double bonds and position of ultimate double bond relative to terminal methyl group.
[d]NSA (no significant amount) implies $<0.01\%$.

not differ markedly from each other in this ratio, as compared with the differences in the ratio 16:0/16:1, but are different from the herring oils.

The distribution of monounsaturated fatty acid isomers in the C_{16}, C_{18}, C_{20}, and C_{22} chain lengths of turbot oils 1 and 2 does not differ notably from recent data for the distribution of these acids in herring oil (Ackman and Castell, 1966) and cod liver oil (Ackman et al., 1967). This is a further reason for not considering these oils as unique, but rather as extremes of normal composition patterns.

TABLE II. Properties and fatty acid percentage compositions of body oils of Newfoundland turbot (or Greenland halibut) *Reinhardtius kippoglossoides*.[a,b]

Sample:	1	2	3
Iodine value (Wijs):	98.5	96.8	92.1
Non-saponifiables (%):	0.49	0.67	0.47
Free fatty acids (%):	–	–	0.53
Fatty acid[c]	Fatty acid methyl ester composition %		
Saturated			
12:0	0.05	0.08	0.06
Iso 13:0	Trace	0.01	–
13:0	0.03	0.03	–
Iso 14:0	0.01	0.02	–
14:0	5.94	6.20	6.54
4,8,12-Trimethyltridecanoic	0.21	0.23	–
Unknown	0.03	0.03	–
Iso 15:0	0.17	0.16	–
Anteiso 15:0	0.08	0.07	–
15:0	0.27	0.27	0.25
Iso 16:0	0.05	0.05	–
Pristanic	0.17	0.22	–
16:0	10.75	11.04	12.04
Iso 17:0	0.17	0.09	–
Anteiso 17:0	0.12	0.07	–
17:0	0.06	0.07	0.58
Phytanic	0.11	0.11	
Iso 18:0	0.06	0.06	–
18:0	1.35	1.55	0.93
19:0	0.09	0.10	–
20:0	0.16	0.21	–
Total	19.9	20.7	20.4
Monounsaturated			
14:1	0.13	0.13	0.56
15:1	0.08	0.08	–
16:1ω9	0.43	0.21	15.35
16:1ω7	14.09	15.10	
16:1ω5	0.51	0.33	
17:1ω8	0.23	0.18	0.07
18:1ω(11+9)	11.60	10.99	17.38
18:1ω7	3.99	3.64	
18:1ω5	0.51	0.49	
19:1ω9 ?	0.01	0.02	–
19:1ω8	0.05	0.07	–
20:1ω(11+9)	15.32	17.13	18.60
20:1ω7	1.31	1.12	
20:1ω5	0.13	0.13	
22:1ω(13+11)	14.83	14.82	17.84
22:1ω9	2.20	1.98	
22:1ω7	0.35	0.40	

(*Continued*)

TABLE II. Properties and fatty acid percentage compositions of body oils of Newfoundland turbot (or Greenland halibut) *Reinhardtius hippoglossoides*.[a,b] — (*Concluded*)

Sample:	1	2	3
Iodine value (Wijs):	98.5	96.8	92.1
Non-saponifiables (%):	0.49	0.67	0.47
Free fatty acids (%):	–	–	0.53

Fatty acid[c]	Fatty acid methyl ester composition %		
24:1ω9	0.72	0.64	0.96
Total	66.8	67.5	70.8
Diunsaturated			
16:2ω7(or 6)	0.07	0.10	0.44
16:2ω4	0.84	0.78	
18:2ω6	0.86	0.88	0.51
18:2ω4 ?	0.09	0.09	–
20:2ω6	0.17	0.11	0.12
Total	2.0	2.0	1.1
Triunsaturated			
16:3ω4	0.26	0.29	0.24
16:3ω3 ?	0.04	0.04	–
18:3ω6	0.07	0.04	Trace
18:3ω3	0.27	0.29	0.18
20:3ω6	0.03	0.02	0.01
20:3ω3	0.05	0.07	–
Total	0.7	0.8	0.4
Tetraunsaturated			
16:4ω3	0.03	0.04	–
16:4ω1	0.47	0.51	0.41
18:4ω3	0.92	0.88	0.77
18:4ω1 ?	0.14	0.13	–
20:4ω6	0.21	0.20	0.13
20:4ω3	0.32	0.23	0.17
Total	2.1	1.8	1.5
Pentaunsaturated			
20:5ω3	4.44	3.46	2.96
21:5ω2 ?	0.29	0.26	0.17
22:5ω6	0.03	0.01	0.16
22:5ω3	0.79	0.57	0.61
Total	5.6	4.3	3.9
Hexaunsaturated			
22:6ω3	3.12	2.88	1.94
Iodine value calc. from GLC	101	98	90

[a]1, laboratory extract of whole dressed fish; 2, laboratory extract of skinless fillets; 3, commercial reduction of filleting scrap.

[b]1 and 2, fish taken in Trinity Bay, Newfoundland, December 1966; 3, fish taken in early fall, 1966, off Newfoundland.

[c]Shorthand notation for chain length:number of double bonds and position of ultimate double bond relative to terminal methyl group.

TABLE III. Chain length percentage compositions[a] and certain ratios of fatty acid types for low iodine value oils.

Chain length	Herring oil sample				Turbot oil sample			Flatfish oil (Igarishi et al., 1962)	Sablefish oil	
	1	2	3	4	1	2	3		This study	Dolev and Olcott (1965)
C_{12}	0.1	0.2	0.2	0.1	0.1	0.1	0.1	–	0.1	–
C_{14}	6.4	7.4	6.6	6.1	6.6	6.1	7.1	5.6	6.9	4.1
C_{15}	0.4	0.5	0.3	0.4	0.5	0.4	0.2	–	0.3	0.7
C_{16}	18.2	20.4	17.8	21.1	29.2	29.5	28.5	22.1	19.8	28.4
C_{17}	0.5	0.5	0.6	0.5	0.4	0.3	0.6	–	1.3	1.0
C_{18}	15.5	15.4	15.1	12.7	19.4	19.2	19.8	31.4	32.1	45.2
C_{19}	0.1	0.2	0.1	0.1	0.1	0.2	NSA	–	0.1	1.0
C_{20}	24.6	23.2	23.8	22.2	22.6	22.2	22.0	23.1	20.3	12.2
C_{21}	0.2	0.2	0.1	0.2	0.2	0.3	0.1	–	0.2	–
C_{22}	31.8	31.4	34.1	35.2	18.3	19.0	20.5	17.3	16.4	6.3
C_{24}	0.8	0.8	0.7	1.0	0.9	0.8	1.0	–	2.2	1.4
Total polyunsaturates,										
experimental	12.4	12.9	9.5	14.4	13.5	11.8	8.8	12.2	7.3	13.7
calculated[b]	10.8	11.7	8.7	13.4	10.2	9.6	8.0	13.6	5.0	4.0
Hexadecanoic as per cent										
of saturated	54.1	54.6	52.3	55.3	54.1	53.4	59.0	62.9	52.7	60.6
16:1 + 18:1	19.4	18.9	19.5	19.0	31.1	30.8	32.7	35.7	35.7	49.6
16:0/16:1	1.3	1.3	1.2	1.0	0.7	0.7	0.8	1.3	1.7	1.3
16:0/(16:1 + 18:1)	0.48	0.56	0.46	0.51	0.35	0.36	0.37	0.35	0.31	0.53

[a]Omitting branched-chain components.
[b]From formula: % poly. = 10.7 + 0.337 (I.V. oil — 100) (Ackman, 1966; Ackman and Eaton, 1966).

Herring

In a previous study of herring oils (Ackman and Eaton, 1966) the August 1964 sample of I.V. 111.6 from Caraquet, N.B. was considered remarkable. Further samples (Table I) suggest that this is not unusual in midsummer oils produced in this area. Superficially the timing of these trends can be associated with changes in water temperatures. Thus the long-term averages for Entry Island, Magdalen Islands were 4.9 C, 9.8 C, 14.8 C, 17.2 C, and 14.8 C respectively in May, June, July, August, and September (L. M. Lauzier, private communication). In Chaleur Bay the maximum water temperature is found in late July–early August, and although the water was not unusually warm in 1965, it may have warmed earlier in the season (A. Marcotte, private eommunication).

The sexual status of the herring influences the fatness of the fish, the spawning period being associated with a low fat content which rises rapidly in a post-spawning period of heavy feeding (e.g. Lovern, 1938; Leim et al., 1957; Wood, 1958; Iles and Wood, 1965). In the areas (Gulf of St. Lawrence) in question, populations of herring may spawn in spring or fall (Jean, 1956; Leim et al., 1957). Rapid deposition of fat of low I.V. would be particularly likely in warmwater periods, and it is, therefore, probable that the summer oils of low I.V. from the Gulf of St. Lawrence come from spring-spawning fish. However, Tibbo (cited in Leim et al., 1957) also observed fat, immature herring in Chaleur Bay in summer.

In southwestern Nova Scotia reduction of adult herring in 1966 and 1967 produced oils which showed a seasonal decline of about 20 I.V. units in late August and early September (R. G. Ackman and C. A. Eaton, unpublished data). Production in this period can thus include oils of I.V. 100–110. The southwestern Nova Scotia stocks spawn in late summer. To our knowledge the trend of decreasing I.V. for these stocks is more closely related to the post-spawning period of feeding than to water temperature but this is a complex question requiring further study.

Newfoundland Turbot and Sablefish

The Newfoundland turbot is being fished on an increasingly large scale and since scrap yields about 15% oil there could be production of upwards of 2 million lb of this oil in the near future if the scrap were processed separately from other groundfish scrap. The properties of hydrogenated turbot oils might differ somewhat from hydrogenated herring oils as a result of the differing fatty acid chain length proportions (Table III), but as discussed above turbot oil is essentially a normal triglyceride marine fish oil.

We are unaware of a comparable oily flatfish for which both yield and oil composition data are available. Most flatfish have modest quantities (1–3%) of flesh fat, of which nearly 1% would be phospholipids with fatty acids of high iodine value (Ackman, 1966). Gruger et al. (1964) report Pacific halibut (*Hippoglossus stenolepsis*) flesh to contain 1.6% lipid with a fatty acid I.V. calculated to be 147. Olley and Duncan (1965) found neutral lipids of high

I.V. in Atlantic halibut (*Hippoglossus hippoglossus*) and sole (*Microstomus kitt*) (Ackman, 1966). Igarishi et al. (1962) recovered 2.3% of acetone-soluble (neutral) lipid from the flesh of the flounder (*Hippoglossoides dubius*). The I.V. was 123.7. Ito and Fukuzumi (1963) carried out a gas chromatographic analysis of the oil of I.V. 109 from a flatfish (*Atheresthes evermanni*). Turbot oil is only slightly similar in fatty acid composition (Table III).

In the absence of much information on low I.V., non-clupeid oils of the triglyceride type such as the turbot oil, we include for comparison a fatty acid analysis of sablefish oil (Table I and III). This species was found by Dolev and Olcott (1965) to contain 9.8% oil in the muscle, mostly triglyceride of I.V. 80. Einset et al. (1957) report an I.V. of 99 for sablefish oil. The fatty acid analysis of extracted sablefish lipid (chiefly triglyceride) (Table I) differs from that reported by Dolev and Olcott (1965) since the GLC column employed by the latter led them to confuse 20:1 with 20:0 and 22:1 with 22:0. Major triglyceride component percentages given by these authors are 14.8, 11.6, 38.0, 6.6, and 4.1% respectively for the fatty acids 16:0, 16:1, 18:1, 20:1, and 22:1. The high proportion of 18:1 is reminiscent of the unusual fatty acid composition of a single codfish recently reported by Jangaard et al. (1966). The sablefish oil examined by Dolev and Olcott (1965) was pooled from three fish and therefore a high proportion of 18:1 is probably normal for this species, possibly because of its deepwater habitat (Lewis, 1962, 1965).

ACKNOWLEDGMENTS

The authors acknowledge the assistance of J. W. Boyd, Fisheries Research Board of Canada, Vancouver Laboratory, Vancouver, B.C. in securing the sablefish; the cooperation of Gortons of Gloucester, Inc., in furnishing herring oil samples; of Northeastern Fish Industries, Ltd., in donating the commercial Newfoundland turbot oil; and of A. R. Johnston, Department of Fisheries of Canada, St. John's, Nfld., in supplying further turbot oil samples.

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Biology of *Gadus morhua* in Ogac Lake, a Landlocked Fiord on Baffin Island[1,2,3]

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ABSTRACT

Gadus morhua L. occurs in Ogac Lake, a salt, meromictic lake on Baffin Island that receives influxes of seawater only during the highest summer tides. Cod of the order of 10,000 of lengths 25 cm and greater and 500 of lengths greater than 60 cm were present. The size ranges for various ages far exceeded those of oceanic populations. Feeding conditions were poor, and sea urchins predominated in the diet. Large cod (greater than 50 cm) were highly cannibalistic, and it was estimated that they consume of the order of 3500 fish of 20–40 cm annually. Maturation occurred at the unusually large size of 85 cm in females, and at about 65 cm in males. Apparently many of the cod never reach these sizes. Spawning was from late May to early July in 1962, and initiation of spawning appeared to be related to light. The hatching of cod larvae coincided with the appearance of the nauplii of the dominant copepod in the lake. Egg size was highly variable and exhibited a curious bimodalism. Variation in vertebral and fin-ray counts was slight in spite of high environmental variability, and thus appears largely genetically controlled. Possibly the first inhabitants came from Greenland stocks, which have high growth rates similar to the faster growing cod in the lake, and similar high length at maturity. Meristic characters also suggest affinity with Greenland rather than Labrador cod. The hydrography of the area and the possibilities of larval drift or adult migration into the lake are discussed. Cannibalism must exert continuing selection for high growth rates, but very poor feeding conditions and hierarchial dominance effects probably prevent general attainment of high growth rates.

INTRODUCTION

Ogac Lake is a salt, meromictic lake located at the head of an inlet on the southern coast of Frobisher Bay, Baffin Island, at 62°52′N and 67°21′W. This area is presumably rising as a result of the retreat of the ice cap, and the lake is semi-isolated, inflows of salt water being restricted to the highest tides in summer.

Interest in the lake was stimulated by reports of Eskimos catching "giant" cod there. Scientific studies were begun in 1951, when the MV *Calanus* of the Fisheries Research Board of Canada was in the area. A 1-day survey revealed that the cod were *Gadus morhua* L., in an unusual ecological situation. The history of further expeditions to the lake is summarized by McLaren (1967a). The material for this paper was collected during these expeditions, and in addition by I. A. McLaren, on a brief visit in 1965. The cod formed only part of the studies at Ogac Lake. For this reason, as well as a desire not to

[1]Received for publication September 2, 1966.
[2]The third paper in a series of studies on Ogac Lake.
[3]Based on a thesis submitted in partial fulfillment of the requirements for the degree of Master of Science from McGill University, Montreal, Que.

J. Fish. Res. Bd. Canada, 24(12), 1967.
Printed in Canada.

overfish this unique population, the material is not as extensive as might be wished.

This population is of particular interest because it is the northernmost population of Atlantic cod on the western side of Davis Strait and is possibly a relict population, and because of the unique hydrographic conditions in which the population is found.

GENERAL HYDROGRAPHIC CONDITIONS IN OGAC LAKE

A detailed description of morphometry and hydrographic conditions is given by McLaren (1967b). The following is a summary of factors of immediate importance to this study.

The lake consists of three basins, referred to as outer, middle, and inner (Fig. 1). The oxygen profile has been found to be similar from year to year, with oxygen depletion occurring at about 20, 25, and 27 m in the three basins respectively. An oxygen concentration of 2.8 ml/liter is considered critical for cod (Sundnes, 1957). No fish were caught deeper than about 20 m.

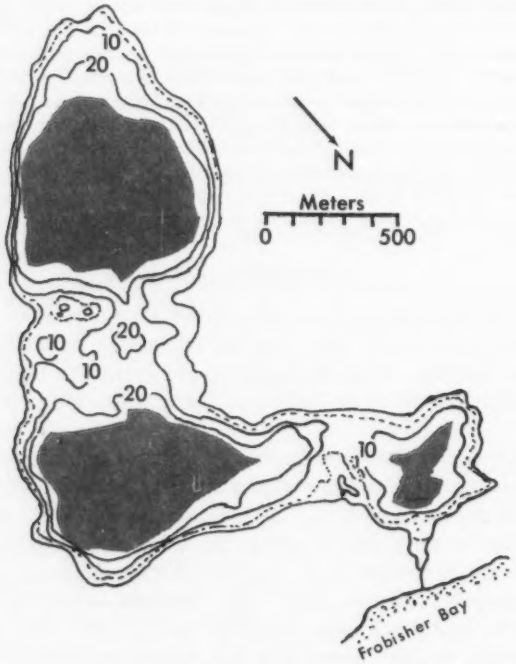

FIG. 1. Bathymetry of Ogac Lake. The 10- and 20-m contours are shown, as well as the anoxic bottom areas in the center of each basin (shaded). The broken lines around the shores are the limits of the ice-worked shelf at 2 m, almost always covered by freshwater.

From 5 to 20 m the salinity in 1957 was maintained within ranges of about 20–28, 17–26, and 14–25‰ in the outer, middle, and innerbasins respectively. Salinities in the deeper part of this depth range are stable from year to year. At depths less than 5 m the water is subject to varying degrees of freshening through runoff, precipitation, and melting. The maximum depth of the freshwater layer was about 2 m in 1952 and 1957, and 3 m in 1962. Cod were rarely noted in the freshwater layer, and generally stayed below 5 m.

The outer basin maintains the lowest temperatures of the three basins, and the inner basin averages warmest. The ranges of temperatures (C) observed in the 1957 season between 5 and 20 m were:

	Early June	Mid-July	Mid-August	Mid-September
Outer	0.1–3.0	3.1–6.4	3.9–8.0	4.1–9.2
Middle	1.0–6.8	3.8–7.4	6.3–8.9	6.3–8.7
Inner	2.1–7.1	4.1–7.8	5.9–8.4	6.8–8.7

Vertical distribution of temperature in 1962 differed from that in 1957, but the mean temperature and the heat budget were about the same.

POPULATION ESTIMATES

METHODS

Fish were tagged and fin-clipped rather haphazardly in 1957. Altogether 50 were marked, but few were recaptured. In 1962, different colored tags were used, and the tags were placed in different parts of the back according to basin of origin. Fish were tagged from July 3 to August 12, and observations taken from August 13 to August 28. Tagging was restricted to fish of greater than 60 cm in the outer basin, and greater than 50 cm in the middle and inner basins, where the fish averaged smaller. Fish smaller than these were not tagged because they were often captured by larger fish on return to the water. Fish were observed on calm days by dropping a jig into the water and counting the fish approaching it, and by counting those seen from the bow of a canoe while passing over demarcated regions. A total of 233 observations were made along the perimeter of the lake in this manner. Observations were recorded as follows: total number observed, number longer than 60 cm, number of 50–60 cm in length, number of very small fish (estimated as less than 10 cm), and number of tagged individuals (Table I).

The outer basin was treated separately from the middle and inner basins combined. This probably does not introduce serious error since over short periods there appeared to be little movement between the two areas, as indicated by the recovery of tagged fish:

Interval between marking and recapture	No. recaptured	No. recaptured in basin other than that of origin
2–26 days	5	0
36–51 days	4	1
3 years	10	5

TABLE I. Field observations and population estimates. See text.

Item	Basin	
	Outer	Middle and Inner
	Field observations	
No. tagged	48 (>60 cm)	64 (>50 cm)
Observed: Total	413	1195
50–60 cm	22	87
>60 cm	48	47
Tagged	15	8
	Population estimates	
Total (>25 cm)	1264 (630–3,100)[a]	8561 (3,500–22,000)
>50 cm	214 (128–430)	960 (535–2,560)
>60 cm	147 (102–245)	336 (128–1,180)

[a]95% fiducial limits.

First, estimates were made of the number of fish of taggable size (i.e. over 60 cm in the outer basin, and over 50 cm in the middle and inner basins) using formula 3.7 of Ricker (1958):

$$\hat{N} = \frac{M(C+1)}{R+1}$$

where $\hat{N}$ is the estimate of the number of fish of taggable size, M the number tagged, C the number of fish of taggable size observed, and R the number of tagged fish observed. Estimates of the number of fish in other length categories were obtained by multiplying the above estimate (N) by the ratio L_{eo}/C, where L_{eo} is the number of fish in the length category to be estimated that were observed, and C is the number of fish of taggable size observed. For example, the number of fish of taggable size (i.e. greater than 60 cm) in the outer basin was estimated as

$$\hat{N} = \frac{M(C+1)}{R+1} = \frac{48(48+1)}{15+1} = 147$$

and the total number in the outer basin was estimated as

$$T = N \times L_{eo}/C = 147 \times 413/48 = 1264.$$

Fiducial limits (95%) were calculated from the binomial distribution charts of Clopper and Pearson (1934), and were applied first to the estimate of N and second to the ratio L_{eo}/C.

The "total" population estimates apply to fish longer than about 25 cm, as few fish smaller than this were caught or observed.

RESULTS (TABLE I)

Fiducial limits of the population estimates are large, and in addition errors may have resulted from the methods of observation. The estimates can only be regarded as giving the order of magnitude, i.e. of the order of 10,000 fish of lengths greater than 25 cm, and 500 fish of lengths greater than 60 cm.

The percentage of the total population found in the outer basin was estimated as 13, and that for the large fish (greater than 60 cm) in the outer basin as about 29. This suggests a congregation of large fish in the outer basin; qualitative observations of large fish there, especially around the entrance from the sea, supported this suggestion. The small fish may be reduced in number by cannibalism, which will be discussed.

GROWTH AND AGE

METHODS

Fish were caught mainly by "jigging"; the sizes taken by this means ranged from 27 to 144 cm. In 1965 a small-mesh gill-net caught 8 fish of 14–22 cm. Because of desire not to overexploit this population, the samples were small, the largest being the 1957 sample of 81 fish.

Otoliths were collected from 222 fish in the years 1951, 1952, 1957, and 1965. The otoliths were fractured at the interruption in the *sulcus acusticus* on the convex side, mounted in modelling clay, and read using a stereoscopic dissection microscope and transmitted blue light.

Interpretation of the ages was complicated by the presence of secondary hyaline zones and indistinct winter zones. This type of otolith structure (Fig. 2) is similar to that described by Hansen (1949) and Otterbach (1954) in *Gadus morhua* from inner Gothaab Fjord in West Greenland and inner Oslofjord in Norway, and appears to be characteristic of non-migratory populations. However, the ages determined are considered reliable, and those that were very doubtful (8 in number) were excluded from analysis. Seventy-one otoliths were read at the Biological Station of the Fisheries Research Board of Canada at St. Andrews, N.B., and by A. W. May at the Marine Sciences Centre, McGill Universtity. My own readings agree with 75% of the readings by the above, and differences were at most 1 or 2 years.

Sixty-two otoliths were measured to back-calculate growth of individual fish. These otoliths were selected for clarity of the winter zones. The surfaces were ground flat by a powered graphite disc. The axis used in measurement (Fig. 2) is defined on nearly all otoliths of the Ogac Lake cod by an indentation in the middle of the hyaline zones on the concave side of the otolith. The axis is not always straight, but was selected because it represented the most consistent aspect in the growth of the various otoliths. Use of the axis was justified by the high degree of log–log correlation ($r = 0.94$) between axis length and

body length. Increments were measured from the origin in the initial opaque growth to the outer edges of the hyaline zones. All measurements were made at 50× in eyepiece micrometer units; 1 unit = 0.007 mm. The estimating equation of the regression (Fig. 3) is:

$$\log_{10} \text{length (cm)} = -1.2707 + 1.2636 \log_{10} \text{otolith radius (eyepiece units)}.$$

From this the length (L_a) at a given age was determined as outlined by Rounsefell and Everhart (1953) from a simple proportionality formula and the otolith radius-body length regression as follows:

$$\frac{V_a}{V} = \frac{L_a - (-1.2707)}{L - (-1.2707)}, \text{ whence } L_a = \frac{V_a}{V}(L + 1.2707) - 1.2707$$

where V_a is the radius to the annulus, V is total otolith radius, L_a is the length at time of annulus formation, and L is the total length, all in $\log_{10}$. Comparison of back-calculated lengths with observed lengths of seven tagged fish recaptured in later years provided a check on the adequacy of the above formula. The calculated and observed lengths agree within a few centimeters (Table II). The check also showed that the age readings were accurate within ±1 year.

Results

An average growth curve for the Ogac Lake cod cannot be calculated because of insufficient sampling over the length ranges at various ages. In any case, the variability in growth rate (Table III) amongst the Ogac Lake cod is of much greater interest than the average.

Cod growth rates in the literature are given in figures for average length or weight at given ages. Variability in growth rate within a population is not reported, presumably because it is not significant. Reference to original data on cod ages and length shows that the variation in growth rates of the Ogac Lake cod is markedly greater than that of oceanic populations (Table III).

Although the data is insufficient to calculate average growth rates, a slower average growth rate in males is suggested by the fact that the male: female sex ratio was 0.43 for ages 2–8 (n = 101) and at ages greater than 8 it is 0.19 (n = 72). If on the average males grow more slowly than females, they will suffer a greater mortality through cannibalism, discussed below.

Length–Weight Relationship

The log–log regression of length on weight (Fig. 4) is described above 40 cm by the equation

$$W = 1369 \times 10^{-8} \times L^{3.08}$$

where W is the weight in pounds and L is the length in cm. At lengths less than 40 cm the exponent appears to be greater, and the fish proportionately

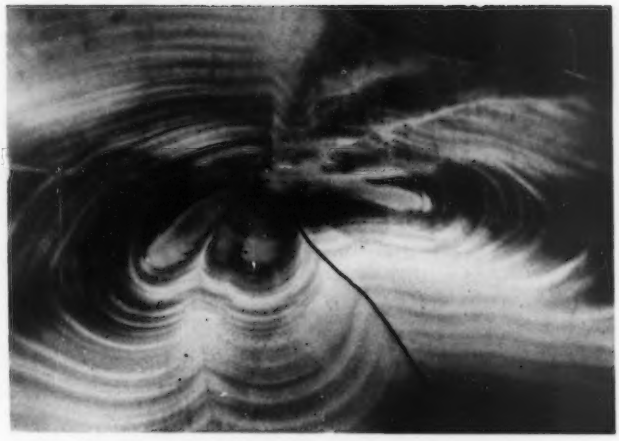

FIG. 2. Sectioned otolith of 13-year-old fish. Axis used in measurement is indicated.

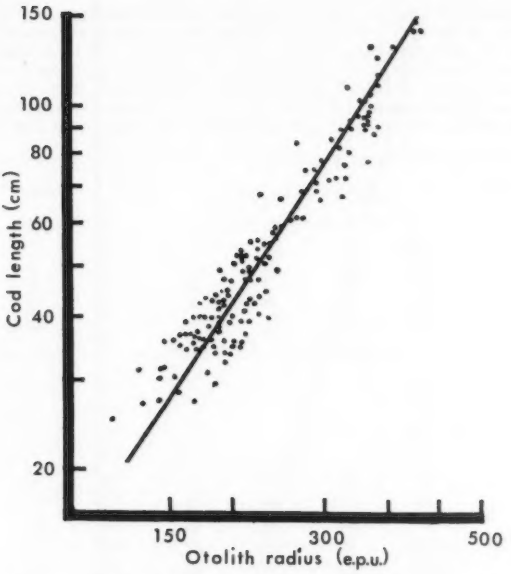

FIG. 3. Log–log regression of length of fish on otolith radius, one e.p.u. (eyepiece unit) = 15.3 μ.

TABLE II. Observed and back-calculated lengths of seven recaptured tagged fish.

At recapture		At first capture		
			Length (*cm*)	
Age (*years*)	Length (*cm*)	Age	Observed	Calculated
9	83	6	66	57 +[a]
11	72	8	61	59 +
12	75	9	63	62 +
12	66	9	59	59 +
12	98	9	95.5	–[b]
13	87	10	72	74 +
15	98	7	59	61 +

[a]Plus signs are used because back-calculated values apply to the end of the winter period. Fish were tagged during the subsequent growing season.

[b]The annuli for ages 10, 11, and 12 on this otolith were observed at one portion of the otolith only, and were very close together. An abrupt decline in growth rate is indicated, probably as a result of tagging.

TABLE III. Extremes of length at given ages for four cod populations. Port Burwell figures are taken from data of the Arctic Biological Station of the Fisheries Research Board of Canada, Ste. Anne de Bellevue, Que., on 664 specimens. ICNAF figures are from Fisheries Research Board of Canada data contributed by A. W. May, Biological Station, St. John's, Newfoundland. This data was taken from several thousand cod caught by inshore otter trawl in an unexploited area, ICNAF 2G, and an exploited area, ICNAF 2J. Figures marked ′ are from back-calculations, and parentheses indicate only one specimen was available in that age group.

	Lower limit (*cm*)				Upper limit (*cm*)			
Age (*years*)	Ogac Lake	Burwell	ICNAF 2G	ICNAF 2J	Ogac Lake	Burwell	ICNAF 2G	ICNAF 2J
1	6′				17′			
2	13′				34′			
3	21′				45′			
4	23′			35	56′			49
5	27′	38	40	37	65′	55	57	58
6	29′	43	41	38	74′	54	60	74
7	31′	44	46	40	90′	58	60	80
8	33′	46	47	41	91	62	65	81
9	33	47	47	48	92	65	66	88
10	40	51	49	50	101	67	70	91
11	40	53	50	51	109	63	70	85
12	58′	53	53	49	112	65	68	99
13	60	53	50	50	118	73	67	90
14	62′	55	56	51	126	71	70	85
15	64′	48	57	53	128	74	73	90
16	66	58	57	63	128	71	72	111
17		64	58	55	141	69	70	103
18		61	58	60		75	67	80
19		62	(60)	70		71	(60)	96
20			(65)	60			(65)	85
21			–	76			–	87
22			(78)				(78)	

thinner, but it is difficult to determine the validity of this without smaller fish. The exponent 3.08 does not differ significantly from the exponent of 3.00 for isometric growth.

The mean weights at given lengths of the Ogac Lake cod compared with those of other populations (Table IV) suggest the Ogac Lake cod are not particularly "fat" or "thin."

FEEDING

A general qualitative description of the stomach contents was carried out in the field (Table V).

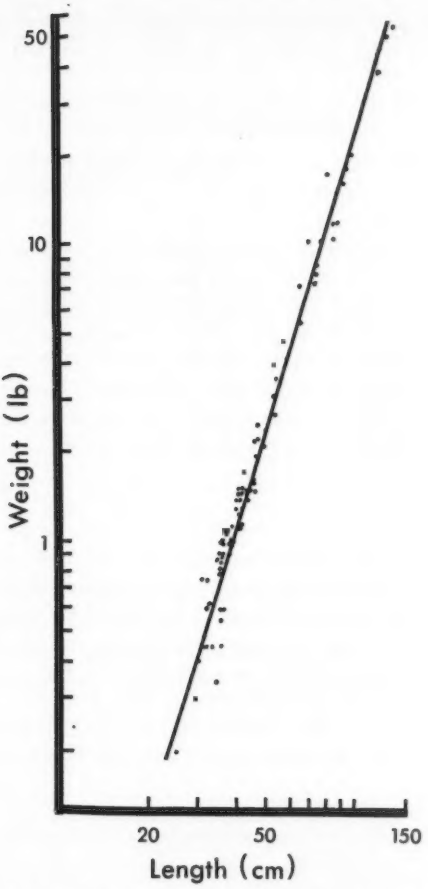

FIG. 4. Log–log regression of weight on length.

Fish of length 14–22 cm feed principally on crustaceans. At greater lengths the diet becomes more varied and the sea urchin *Strongylocentrotus droebachiensis*, molluscs (mostly *Saxicava arctica*), and the polychaete *Cistenides* (*Pectinaria*) *granulata* become important constituents of the diet. At lengths of 50 cm and greater, smaller cod (up to 40 cm) are a major source of food for these large cod. The lack of cod under 20 cm in stomachs of larger cod suggests that behavioural differences prevent intense predation on the smallest cod. These were observed lurking among boulders on steep slopes, and were caught only at nighttime by nets.

It may be assumed that prior to a length of 14 cm the food consists mainly of small crustacea. Marak's (1960) observations of the food habits of larval

TABLE IV. Weights at given lengths for four cod populations. Labrador data from May (MS, 1966), west Greenland from Ruivo (1966), and Banquereau from Ancellin (1955).

	Weight (*lb*)			
Length (*cm*)	Ogac Lake	Labrador	West Greenland	Banquereau (Nfld.)
40	1.2	1.3	–	1.1
50	2.3	2.5	2.4	2.2
60	3.9	4.0	4.4	3.8
70	6.6	7.1	6.7	6.9
80	9.9	10.5	9.6	9.5
90	14.5	15.5	14.5	15.5
100	20	21.5	–	–
110	26.5	29	–	–
120	34.5	37	–	–
130	44.5	47	–	–
140	55.5	61.5	–	–

cod may be summarized as follows: prior to yolk-sac absorption, copepod nauplii are the principal source of food; from a length of 0.4 to 1.3 cm, small copepods may be the chief food; above this size, any size copepods may be taken and young amphipods and euphausids begin to be eaten. The time of spawning in the lake will be shown to coincide with the appearance of nauplii of the most abundant copepod in the lake, *Pseudocalanus minutus*.

Of particular interest is the cannibalism of the larger cod on the smaller. No cod longer than 40 cm and none shorter than 20 cm were found in the stom-

TABLE V. Percentages of cod with food in stomachs in which various food items occurred.

	Cod length group (*cm*)		
Food item	14–22	30–49	50+
Seaweeds	–	9.6	19
Polychaetes	20	25	5.7
Amphipods	100	15	13
Molluscs	–	15	15
Sea urchins	–	67	60
Brittle stars	–	7.7	5.8
Small fish	–	3.8	–
Cod	–	–	21
No. examined	6	59	62
Empty	1	7	10

achs of the larger cod. From the estimate of the number of cod greater than 50 cm (Table I) the number of cod eaten per day in the lake was estimated as

$$\frac{\text{(No. of large cod)} \times \text{(avg no. of cod per stomach)}}{\text{(time required to digest a cod)}}$$

$$= \frac{1027 \times 0.177}{4\text{–}6 \text{ days}} = 30\text{–}45.$$

The limits of digestion time are those used by Powles (1965) in estimating plaice mortality as prey for large cod. If active feeding continues for a period of 100 days (the approximate time the lake is ice-free), then several thousand or more cod between the lengths of 20 and 40 cm are eaten annually. This represents at least one-third of the standing crop of cod in this length interval. The intense cannibalism is probably responsible for the decrease in number of males relative to females, and is probably sufficient to account for the sharply increased lower limit of length from 40 to 58 cm observed between ages 11 and 12 (Table III).

MATURATION

Methods

In August of 1965 observations were made in the field by I. A. McLaren on the state of the gonads. Mature fish were recognized according to the descriptions of Sorokin (1958, 1960). At this time all mature gonads were spent. There was somewhat more difficulty in classifying males with certainty than females.

Results

The sample of males is small, but maturity appears to be reached at sizes from 60 to 70 cm; females begin spawning when they have reached lengths of 80–90 cm (Table VI). The lowest age of spawning males was 7, and non-spawning males included individuals to age 9; spawning females were from age 9 up, and non-spawning females included individuals to age 13. Initiation

Table VI. Percentages of mature cod in given length intervals (n = no. examined).

Length interval (*cm*)	Males		Females	
	%	*n*	%	*n*
50–69	29	7	0	10
70–79	100	3	0	6
80–89	100	2	60	5
90 and over	–	–	100	15

of spawning in females is thus primarily a function of length, and this is probably also true of males.

The lower length and age at maturity of males is in agreement with observations on many populations (e.g. Thompson, 1943), and is probably related to a generally lower growth rate in males.

The length at which spawning is initiated in the Ogac Lake cod, particularly in females, is unusually high (Table VII).

TABLE VII. Average lengths and ages at first spawning of *Gadus morhua* from various areas.[a]

Area	Avg length	Avg age	Reference
Labrador			May (MS, 1966)
Males	43.9	5.8	
Females	49.8	6.5	
West Greenland northern districts			Hansen (1949)
Year 1917	–	8.6	
1924	84	8.4	
1934	74	7.8	
1936	73	6.9	
SW Grand Bank	73	7.5	Fleming (1960)
Flemish Cap	57	6.0	" "
Oslofjord (females)	39	2.5	Otterbach (1954)
Ogac Lake			
Males	65	–	
Females	85	–	

[a]Except where stated, males and females are combined.

SPAWNING AND EARLY DEVELOPMENT

METHODS

In June and early July of 1962 vertical plankton hauls were made from the ice through natural fissures and holes. The stations, rather evenly spaced within each of the three basins (map on Fig. 5), totalled 49. The net was hauled from the bottom or, in deeper water, from below the anoxic limits at 30–31 m. The net used was ½-m diam and of #0 mesh (aperture 0.57 mm), and was presumably 100% efficient for non-motile eggs. Only newly hatched larvae were taken in the plankton net, and later stages probably escaped. Cod eggs were removed from the samples and examined under a microscope. The individual eggs were classified into one of 12 stages of development following the description of Meek (1924) for the 12-day development of cod eggs at 5.5 C. Egg diameters were measured under 25× magnification by use of a micrometer eyepiece. One eyepiece unit (e.p.u.) = 15.3 μ.

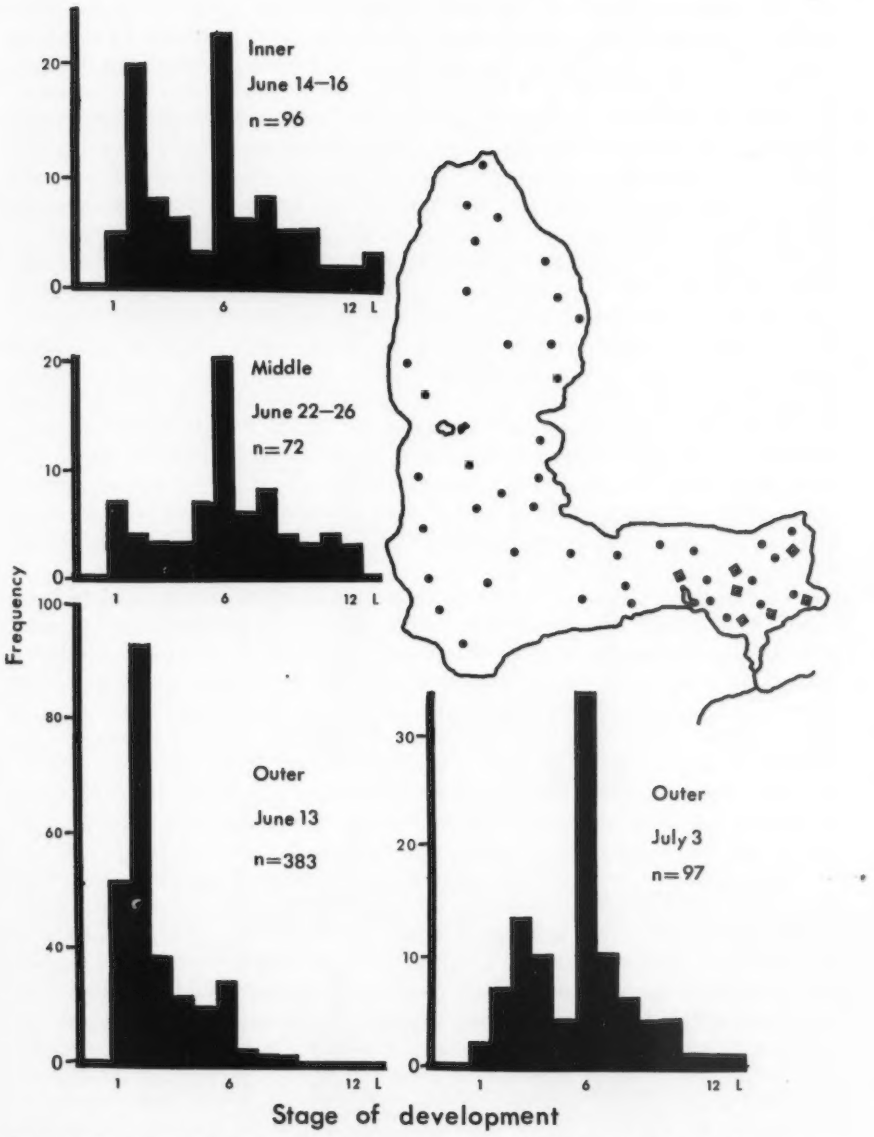

FIG. 5. Frequency distributions of developmental stages 1–12 of eggs and larvae (L). n = no. of eggs and larvae in sample. The insert shows the sampling stations in each basin. The squares in the outer basin are for the series of June 13.

Results

Development time of cod eggs is dependent on temperature (Apstein, 1909). The highest stage of development in the outer basin on June 13 was stage 9 (Fig. 5). If this egg developed at the average temperature between 5 and 20 m, approximately 1.5 C in 1957, then it would have been spawned 22–25 days previously, or if it had developed at a somewhat higher temperature of 2.5 C, about 20 days previously according to the temperature-development time tables of Apstein (1909). The highest stage of development in the inner basin at this time was newly hatched larvae. These would have required 22–26 days to develop at the somewhat higher average temperature of 3.5 C, or 20 days at 5 C. This suggests that spawning began in both basins about May 20–25. However, it is probable that more advanced stages of larvae were present in the inner basin but not captured by the net, and that spawning there began somewhat earlier than in the outer basin. Most eggs in Ogac Lake were hatched by the beginning of July, only a few in advanced stages being taken in plankton tows in the middle and inner basins at this time, and few stage one eggs being found in the outer basin. *Pseudocalanus minutus*, the most abundant copepod in the Lake, reaches maximum numbers at this time (McLaren, MS, 1961), and is thus available as food for cod larvae. Spawning in 1962 was from the latter half of May to the first part of July, a period of about 1½ months. Spawning periods of oceanic populations generally extend from 3 to 6 months (Wise, 1961).

Gonad development is known to be influenced by both light and temperature (Alm, 1959). Temperature in Ogac Lake varies vertically, seasonally, and between basins. If it were the principal controlling factor it would be unlikely to cause synchrony of spawning with the zooplankton cycle, especially with the appearance of copepod nauplii as food for young cod, or to result in the relatively short spawning period. The phytoplankton maximum, and accordingly the zooplankton cycle, are retarded in the outer basin as a result of a later departure of the ice-cover there (McLaren, MS, 1961). If as suggested above, cod spawning is also retarded in the outer basin, then it is appropriately timed, and is presumably a response to the same factor, i.e. light.

More eggs per net haul were taken in the outer basin than from the other two basins. Assuming that the eggs on June 14–16 in the inner basin, June 22–26 in the middle basin, and July 3 in the outer basin (Fig. 5) represent about the same time intervals since the beginning of spawning in the three basins, as suggested by the similarity of their stage distributions, and assuming that they have suffered similar degrees of mortality, the numbers of eggs in the middle and inner basins combined and in the outer basin should indicate the relative concentrations of spawners in these two areas. The average net sample (excluding those from over bottoms less than 6 m, in which almost no eggs occurred) produced 12.1 eggs in the outer basin and 5.4 eggs in the middle and inner basins combined. However, the area of the middle and inner basins combined is about 6.9 times that of the outer basin. This suggests that about 25% of all eggs were spawned in the outer basin. The number of spawners in

the outer basin may be considered proportional to the number of fish over 60 cm length occurring there, estimated previously as 29% of the total number over 60 cm. These two independent estimates of the proportion of spawners in the Lake which occur in the outer basin are in fair agreement.

Egg Diameters and Vertical Distribution of Eggs

A series of vertical hauls through the water column from the surface to 6, 9, 12, 15, 18, and 19.5 were taken at one location in the outer basin. The modes of the egg size frequency distributions shift towards a smaller size with increasing depth, and a second mode of smaller size appears in the deepest tows (Fig. 6). It is concluded that eggs occurred throughout the water column and that smaller eggs occurred with increasing depth.

The small eggs (80–100 e.p.u.) were peculiar in two respects. First, the vitelline membrane was darkly pigmented, and second, distorted development of the blastodisc prior to epiboly was observed in 75% of these eggs. The

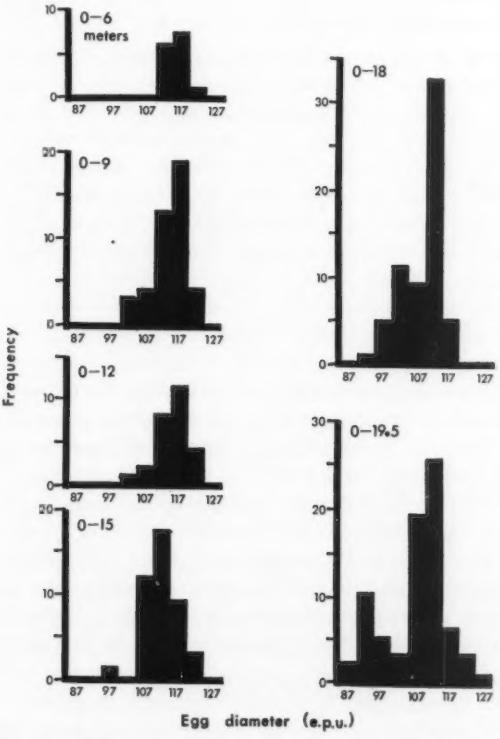

FIG. 6. Frequency distributions of diameters of eggs taken in vertical tows from the stated depths to the surface at one location. One e.p.u. (eyepiece unit) = 15.3 μ.

pigmentation was observed when the eggs were first examined in February 1965, but had bleached out when they were re-examined a year later. Dr B. d'Anglejan of the Marine Sciences Centre, McGill University, suggests (personal communication) that such pigmentation may result from the presence of H_2S, forming iron sulfide compounds in the membrane, and that oxidation occurs in time with resulting loss of pigment. These eggs were taken only from the deepest tows, and must have been in regions of low oxygen concentration. Within a short distance deeper the water is anoxic, and the attendant H_2S might diffuse into the sampled layers. Either the low oxygen concentration or the presence of H_2S may have been responsible for the distorted development of the blastodisc. The fact that these two peculiarities were observed only in the smaller eggs of the surface to 18 and 19.5 m tows suggests that small eggs (80–100 e.p.u.) occurred only between 15 and 19.5 m.

The range in egg size in the Ogac Lake samples is greater than that found elsewhere (Table VIII). Variations in egg diameter produced by differences in water temperature have been observed by several investigators (Wheatland, 1956; Rass, 1936; Fish, 1928). This variable effects changes in egg size just

TABLE VIII. Range in diameters of developing eggs of *Gadus morhua* from various areas.

Location	Egg diameter (*mm*)	Reference
Barents Sea	1.13–1.63	Rass (1936)
West Greenland	1.37–1.65	McGill collections
Halifax Hbr.	1.12–1.55	McKenzie (1940)
Gulf St. Lawrence	1.15–1.50	Dannevig (1919)
Grand Bank	1.15–1.40	Fish (1928)
Labrador Current	1.35–1.55	" "
Ogac Lake	1.23–1.80	

prior to, or at the time of fertilization (Fish, 1928). However, the order of differences produced by temperature is not sufficient to account for the variation found in the Ogac Lake samples. Salinity differences may also be discounted since in both large and small eggs the egg is closely pressed against the vitelline membrane. The bimodal nature of the egg-diameter distribution (Fig. 6) is curious. Bimodalism would not be caused by a continuous environmental variable. It is suggested, therefore, that the differences in egg diameter are established prior to shedding of the eggs. In freshwater fishes the feeding conditions, size, and growth rate of the adult appear to influence egg diameter (Brown, 1957), but this has not apparently been noted for marine fishes.

MERISTIC CHARACTERS

The vertebral numbers and second dorsal fin-ray counts of the Ogac Lake cod are closest to those of the Greenland and Iceland populations of the adjacent cod populations (Table IX).

TABLE IX. Vertebral and second dorsal ray numbers of various populations of Atlantic cod. Port Burwell numbers are from Vladykov (1933) and Arctic Biological Station of Fisheries Research Board of Canada, Ste. Anne de Bellevue, Que., data; all other numbers are from Schmidt (1931). All figures include the urostylar half vertebra.

Location	Vertebrae	D_2
Port Burwell	55.90	21.00
Belle Isle	55.46	20.86
North Newfoundland	55.31	20.52
SE Newfoundland	54.91	20.48
Gaspe	53.58	19.96
West Greenland	53.60	20.32[a]
South Greenland	53.42	20.01
East Greenland	53.14	20.04
East Iceland	53.26	19.94
West Iceland	52.29	19.51
Ogac Lake	53.14	19.40

[a]West Greenland D_2 counts of Hansen (1949) include several areas with averages less than 20.

Several factors such as temperature, salinity, carbon dioxide, light intensity, and oxygen may influence meristic characters (Lindsey, 1962). Tåning (1946) has shown that the influence of environmental factors on several meristic characters, including vertebral number and number of rays in the second dorsal fin, occurs during the development of eggs. The range of developmental conditions to which the Ogac Lake eggs are subject is probably greater than that encountered by most oceanic populations. Yet the vertebral number in Ogac Lake ranges over three figures (52–54), whereas most of Schmidt's (1930) figures include ranges of four to five figures. The low variability of the Ogac Lake counts probably reflects the lack of mixing with other populations and a well inbred population. At any rate, the data imply that genetic variability is more important than the environment in determining meristic characters of cod. Possibly the meristic counts of the Ogac Lake cod reflect those of the first inhabitants of the Lake.

GENERAL DISCUSSION

The population of *G. morhua* in Ogac Lake is unique in several respects. Most striking is the great variability of growth rates, and particularly the maintenance of a very high growth rate by some individuals in this poor environment. Maturity is attained at an unusually large size in females, and apparently a large portion of the population never matures. The wide variation in diameters of the eggs and the bimodal distribution of egg diameters are also curious phenomena.

Brown (1957) discusses the "size hierarchy effect," a kind of "Pecking Order" among fishes. In any brood of trout raised under the same environmental

conditions, and with an excess of food available, certain individuals establish a dominance to others with respect to feeding and growth. The actual size of the largest fish from a brood depends on the time that dominance is established and how effectively this is done; once dominance is established by certain fish, growth or feeding is inhibited in the smaller fish, possibly through stress-produced ACTH. When dominant individuals are removed, previously slower-growing fishes take their places. The normal variability of growth rates within cod populations might be accounted for by Brown's hierarchial effect. Nikolski (1963) discusses the work of Poliakov (1958) who showed in pond experiments with carp that when feeding conditions are impoverished, there occurs a reduction in growth rate, and also an increase in the variability of growth. The extremely low growth rates in some Ogac Lake cod are understandable; any population which relies on sea urchins as its major source of food is feeding in very poor conditions. What has to be explained in this situation is not the very low growth rates of some individuals, but the fact that the maximum growth rate appears to be much greater than that found in nearby, better-fed populations. For this to occur, the first inhabitants of the lake must have had the potential for the high rates observed, and some factor must at present encourage high growth rates.

Cannibalism must exert a strong selective pressure for high growth rates. It was suggested earlier that this factor was responsible for a rapid shift upwards in the observed lower limits of length between ages 11 and 12. Slow-growing cod that are subject to cannibalism for 9-12 years must suffer virtually 100% mortality by the end of this time. Faster-growing individuals, on the other hand, are subject to such high mortality for only 3–5 years, and will have a much lower overall mortality rate.

Spawning is initiated at a very high length, and at this time in the history of the population, spawning is restricted to the faster-growing fish. The population as it is now favors maintenance of a very high growth rate by at least some individuals, in spite of the very poor feeding conditions.

Even in the presence of selective pressure exerted by cannibalism, however, the high growth rates and high length of first spawning could only occur if the invaders of the lake possessed the potential for these factors. A landlocked population of *G. morhua* on Kilden Island in the Barents Sea, for example, is described as "small" (Zhadin and Gerd, 1963). Populations of lake trout in the Northwest Territories which are confined to small lakes and in which cannibalism occurs, do not have increased maximum growth rates or notably increased variation in growth (Dr L. Johnson, Arctic Biological Station, Fisheries Research Board of Canada, St. Anne de Bellevue, P.Q., personal communication). It seems improbable that the Ogac Lake cod could be derived from stocks in northern Labrador, which have a maximum length at age 10 of 70 cm (101 cm in Ogac Lake) and which spawn at an average length of less than 50 cm (May, MS, 1966). The West Greenland populations, however, have individuals as large as 90 cm at 10 years of age and spawn at average lengths within 70–85 cm (Hansen, 1949). If the first inhabitants of the lake

had a high growth rate and high length at first spawning, then the selective pressure of cannibalism would be sufficient to maintain these, and perhaps increase them somewhat. Environmental shortcomings and probably the size hierarchy effect would prevent attainment of high growth rates by the whole population.

The meristic characters of the Ogac Lake population also suggest affinity with the West Greenland populations rather than with the Labrador cod. Larval drift from the coast of Labrador into Frobisher Bay is virtually impossible since the Labrador Current will take eggs and larvae south. Hansen (1955, 1956) found in July and August increasing numbers of larvae from the coast of Greenland to 60°W (63°N), the most westerly stations taken. Poulsen (1960, 1961) and Hansen (1962) raise the question of the fate of these larvae: are they lost, or do they get a chance to settle on the Greenland Banks or the coast of Labrador? Conceivably some might drift into Frobisher Bay. Surface temperatures in the latter part of the summer in the Canadian Current in this area are above 1.8 C (Dunbar, 1951), the temperature considered critical for cod larvae (Tåning, 1953). Tidal inflows could carry larvae into Ogac Lake, where temperatures are favorable for further development and attainment of demersal habit, which occurs at about 3 months of age (Hansen, 1949). However, eggs and larvae of *G. morhua* have not been found in Frobisher Bay.

Temperatures and circulation may have been much more favorable during certain periods in the past. Minimum temperature is the principal limiting factor in the northern distribution of the Atlantic cod (Hachey et al., 1954). As a result, the northern limits of distribution, the location of spawning areas, and the abundance of cod in northerly regions all vary considerably with periodic fluctuations in hydrography. Within recent years, a few cod have been taken at 150–200 fath off the mouth of Frobisher Bay (Fisheries Research Board of Canada, 1960) and, some have been observed at Resolution Island (Fisheries Researd Board of Canada, 1952). No cod are known from Frobisher Bay. On the West Greenland coast they are taken as far north as Upernavik (Hansen, 1949). Changes in abundance of cod in West Greenland are well known. In the 1820's and 1840's cod were numerous in the West Greenland area, but were not found again in large numbers until 1917. From then until the present a large fishery has existed (Hansen, 1949).

Dunbar (1955) discusses fluctuations in the marine climate of this area. Water temperatures in Davis Strait are moderated by the relative and absolute contributions of Atlantic and Polar waters. The West Greenland Current is made up of water contributed from the (cold) East Greenland Current, the (warm) Irminger Current, and Atlantic water from the Labrador Sea. As the West Greenland Current flows north, part of it branches westward, joining the Canadian (Polar) Current flowing south along the Baffin coast to form the Labrador Current at the latitude of Hudson Strait. Increased temperatures of the West Greenland Current in recent years are a result of greater contribution of the Irminger Current, associated with overall intensification of meridional circulations. At the same time, an equivalent increase in water temperatures in the Eastern Canadian Arctic is buffered by increased flow of the

Canadian Current. Stronger resulting geostrophic forces also cause the Canadian Current to be pressed more strongly against the western side of Davis Strait and the West Greenland Current to be pressed more strongly against the eastern side. However, Dunbar suggests, at certain lesser intensities of circulation, the transport and geostrophic forces of the two currents may be in such a balance that the Atlantic influence on the Western side of Davis Strait is greater than at present, and perhaps greater on the western side than on the eastern side. Biological evidence suggests that the 1880's was one such period. Adult *G. morhua* might have migrated westward during such a period and entered the lake.

Whether the differences in egg diameter have any relationship to the wide range of growth rates can only be surmised. The relationship of egg diameter to final size of fish is not clear. Large egg size has been found by some investigators to produce a larger larva, and this size advantage may be maintained (Brown, 1957). It was suggested above that variation in egg diameters, including the curious bimodalism, is established before spawning. The whole situation deserves further study.

ACKNOWLEDGMENTS

The many persons who assisted at Ogac Lake have been acknowledged in the introductory paper to this series (McLaren, 1967a).

I wish to thank Dr I. A. McLaren, my research director at McGill University, who collected most of the material and provided guidance.

A. W. May of the Fisheries Research Board of Canada, Biological Station, St. John's, Newfoundland, was most helpful at McGill University in instructing the author in the techniques of age determination, and also made available certain data used in this paper.

Various members of the Arctic Biological Station of the Fisheries Research Board of Canada, St. Anne de Bellevue, Que., including Dr E. H. Grainger, J. G. Hunter, and Dr L. Johnson, provided data and information.

The work was in part supported by the National Research Council of Canada.

I also wish to express my gratitude for the financial help given me through a McConnell Memorial Fellowship at McGill University.

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Effects of Tagging and of Fin-clipping on the Survival and Growth of Atlantic Salmon Between Smolt and Adult Stages[1]

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ABSTRACT

Rates of recapture of Atlantic salmon marked as naturally produced smolts in the Northwest Miramichi River, New Brunswick, were 2.9 for tagged and 3.9% for fin-clipped grilse and 0.7 for tagged and 1.8% for fin-clipped larger salmon. There are indications that survival to the adult stage is much higher for unmarked smolts than for tagged or fin-clipped fish. Length measurements of 117 tagged, 607 fin-clipped, and 301 unmarked grilse taken above tidehead in the Notrhwest Miramichi showed that those entering freshwater early in the season were smaller that those entering later. Tagged grilse were shorter than fin-clipped grilse which returned at the same time, and the fin-clipped grilse were shorter than unmarked ones. Rates of increase in size among tagged, fin-clipped, and unmarked grilse during the season of return to freshwater (June through October) did not differ significantly.

INTRODUCTION

Tagging and fin-clipping are commonly used to identify fishes in studies of age and growth, migration, population dynamics, and behavior. It is important to know whether or not a particular means of identification affects the mortality rate, behavior, swimming performance, catchability, or growth of the fish. This study gives data on the effect of tagging and fin-clipping at the smolt stage on the survival and growth of Atlantic salmon (*Salmo salar* L.) during sea life.

Naturally produced smolts have been tagged or fin-clipped in the Northwest Miramichi River, New Brunswick, to study the early- and late-running stocks (Saunders, 1967) and to provide data on the contributions of salmon from that river to various commercial and angling fisheries. This paper is based on recaptures of grilse in 1963 and of larger salmon in 1964 and 1965 which were tagged or fin-clipped as descending smolts in 1962.

In this study the term *grilse* refers to fish which mature and return to freshwater after only 1 year at sea. Larger salmon are those which spend 2 or more years at sea before returning to spawn for the first time.

The data show that the rate of recapture of tagged grilse and larger salmon was lower than that of fin-clipped fish. There are also indications that the survival rate of unmarked grilse is several times higher than that of tagged and fin-clipped fish. Studies of the lengths at return of the various

[1]Received for publication June 2, 1967.
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J. Fish. Res. Bd. Canada, 24(12), 1967.
Printed in Canada.

groups of fish revealed that tagged grilse were shorter than fin-clipped and unmarked fish.

MATERIALS AND METHODS

Naturally produced smolts in the Northwest Miramichi were captured during the seaward migration in May–June 1962 at counting fences located at Curventon and Camp Adams which are respectively 7 and 40 miles above tidehead (Fig. 1). Descriptions of the counting fences are given in Henderson

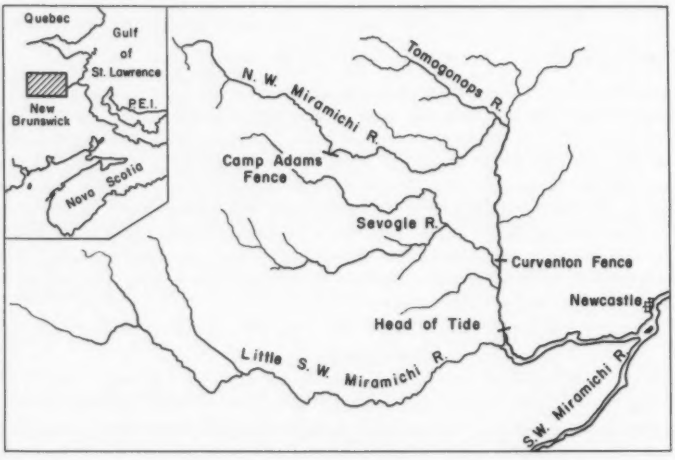

FIG. 1. Northwest Miramichi River system showing locations of counting fences and tributaries.

et al. (MS, 1965). At Camp Adams 1582 smolts were tagged; an additional 1978 were marked by removing the adipose and left pelvic fins. At Curventon 4030 smolts were tagged; 14120 were fin-clipped using the same combination of fins as used at Camp Adams. Tags were serially numbered, made of blue plastic, and attached with pliable stainless steel wire of 0.3 mm diam. The method of attachment was patterned after the Swedish smolt tag (Carlin, 1955) (Fig. 2).

Figure 3 shows the patterns of the smolt run at Camp Adams and Curventon and shows when fish were tagged and fin-clipped. Mean lengths of three samples of smolts taken at Camp Adams near the beginning, middle, and end of the run show a slight decrease in length during the run.

Since the same fin-clip combination was used at both counting fences, it was impossible to distinguish, among returning grilse and larger salmon, those marked at Camp Adams from those marked at Curventon. Recaptures of these fish are combined as a single sample. In order that samples of tagged and of fin-clipped grilse may be comparable, the returns of grilse tagged as smolts at Camp Adams and Curventon are also combined.

Recaptures of tagged and fin-clipped adults (grilse and larger salmon) were made in various angling and commercial fisheries and at the counting fences. Data from all these sources were used in the study of survival rates. The data pertinent to the study of effect of tagging and fin-clipping on size are those for date and length at recapture above tidehead in the Northwest Miramichi. Owing to uncertainties in the data regarding fish caught commercially, only those recaptures at Curventon fence and in the angling fishery between tidehead and the counting fence are included in the consideration of grilse length. Most of the recapture data for tagged and fin-clipped grilse were collected at Curventon fence. Data from tagged and fin-clipped fish angled in the river below the counting fence were included if Fisheries Research Board staff verified marks, length, and date of recapture. All data for unmarked grilse were collected at Curventon fence.

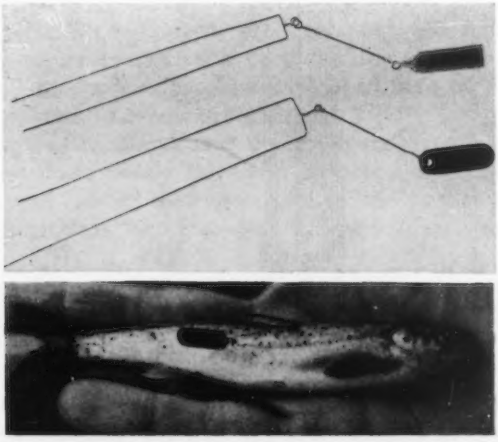

FIG. 2. *Top*, Swedish smolt tag and a modified Swedish tag of the kind used in this study; *bottom*, a smolt with one of the latter attached.

Measurements are of total length with caudal fin relaxed. When there were few grilse in the trap, all were measured and released on the upstream side of the fence. If there were many fish in the trap, a longitudinal partition was dropped to isolate a few of them at a time for ease in handling and in searching for previously applied tags or fin-clips. Unmarked grilse were measured and released until it was decided that a sufficient number of the day's sample had been examined. Subsequent lots were isolated, examined for previously applied tags or fin-clips, and then released without being measured. We do not consider that this procedure of selecting grilse for measurement produced any bias for larger or smaller fish.

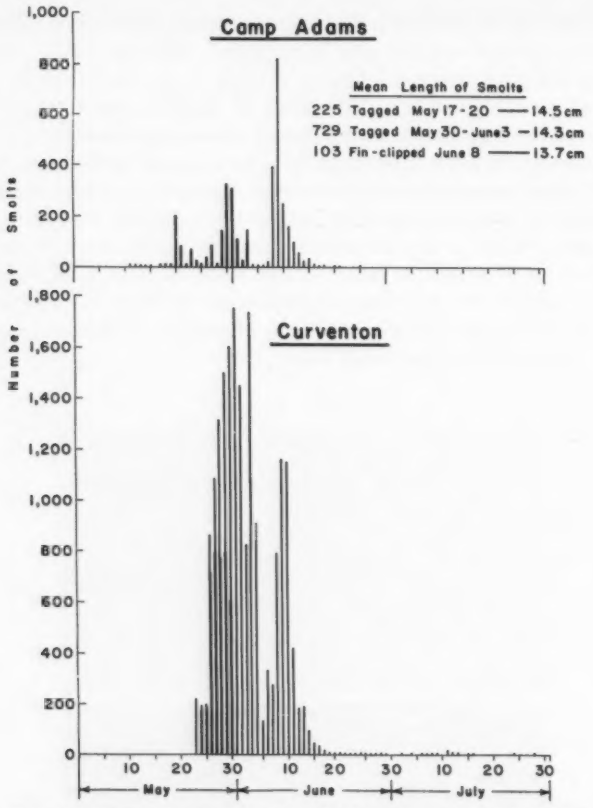

FIG. 3. Seasonal patterns of smolt descent past Camp Adams and Curventon in 1962. Numbers of fish tagged and fin-clipped each day are indicated by thick and thin lines respectively. Mean total lengths are given for three samples of smolts collected at Camp Adams.

RESULTS

SURVIVAL

Total and percentage recaptures of tagged and fin-clipped grilse and larger salmon are summarized in Table I. Total rates of recapture for tagged fish were 2.9 and 0.7% as grilse and larger salmon respectively; for fin-clipped fish they were 3.9 and 1.8% respectively. The figure for fin-clipped grilse is an adjusted one arrived at by subtracting an appropriate number of fish. This number is based on tagged fish which dropped back below Curventon fence during periods of severe mining pollution during 1963 and subsequently reascended (Saunders and Sprague, 1967). In addition to the tagged and fin-clipped grilse caught in 1963, 5376 unmarked grilse were examined at Curventon fence in that year.

TABLE I. Summary of adult recaptures of salmon tagged and fin-clipped as smolts at Camp Adams and Curventon in 1962. Number tagged – 5,612; number fin-clipped – 16,098.

	Tagged		Fin-clipped	
	Grilse (1963)	Larger salmon (1964–66)	Grilse (1963)	Larger salmon (1964–66)
Commercial fisheries	29(0.5%)	35 (0.6%)	35 (0.2%)	274 (1.7%)
Angling	23 (0.4%)	3 (0.05%)	72 (0.4%)	3 (0.02%)
Counting fences	110 (2.0%)	1 (0.02%)	532 (3.3%)	13 (0.08%)
Total recaptures	162 (2.9%)	39 (0.7%)	639 (3.9%)	290 (1.8%)

GROWTH

The number of grilse measured during the period June 10–October 18, 1963, were: tagged, 117; fin-clipped, 607; unmarked, 301. The results showed that grilse entering freshwater early in the season were smaller than those entering later and that returning grilse which had been tagged or fin-clipped as smolts were shorter than unmarked fish.

All the data for length and date of capture are given in scatter diagrams (Fig. 4–6). These show clearly the trend of increasing length as the season progressed. Lines of best fit were calculated by the method of least squares. The regression equations for these data are as follows:

$$\text{Tagged} \quad y = 50.48 + 0.048x$$
$$\text{Fin-clipped} \quad y = 50.55 + 0.059x$$
$$\text{Unmarked} \quad y = 51.19 + 0.054x$$

where x = time in days from June 1 and y = length in cm. The lines for each set of data are reproduced in Fig. 7 for comparison of slopes.

Analysis of co-variance was used to test for differences in growth rate (slope) and mean length in the three samples. There is no significant difference in slope among the three groups. The mean length of the tagged grilse was significantly less ($p < 0.01$) than those of both fin-clipped and unmarked fish. The difference in length between fin-clipped and unmarked grilse did not reach the $p = 0.05$ level of significance.

A more detailed examination of the effects of tagging and fin-clipping was made by dividing each set of data in Fig. 4–6 into its early and late components. Saunders (1967) has shown that there are distinct early (June–July) and late (September–October) runs of salmon in the Northwest Miramichi. Grilse sampled from day 0 to 61 (June 1–July 31) are considered to be early-run and those from day 100 to 140 (September 8–October 18) to be late-run. Separate comparisons among tagged, fin-clipped, and unmarked grilse have been made for the early- and late-run samples by pooling all the fish in each category and ignoring the precise dates of capture of individual fish. Table II

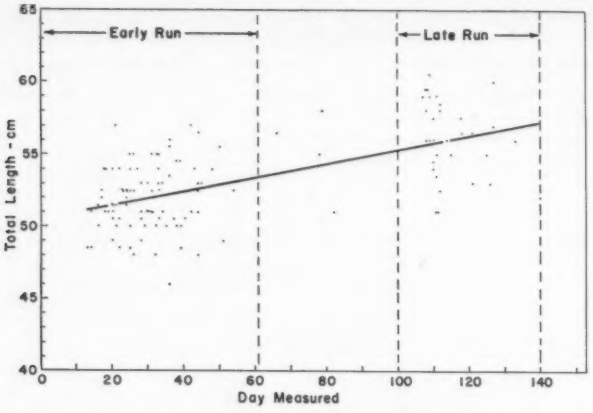

FIG. 4. Relation between length and date of recapture of tagged grilse in freshwater. Fish were tagged as smolts at Camp Adams or Curventon. In the time scale, day 0 is June 1.

gives mean lengths and dates of capture of early and late components of the three samples.

Since the fish were growing during the periods of collection, it was necessary to adjust the mean length for differences in mean capture dates. The mean lengths of tagged and unmarked groups were adjusted to the mean dates for the fin-clipped fish since these were the largest samples. The adjustment was made by multiplying the difference in date by the slope of the regression line for the appropriate group. The resulting adjusted values are given in Table III.

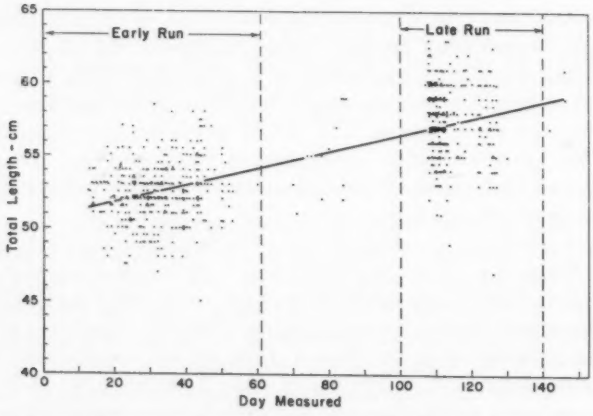

FIG. 5. Relation between length and date of recapture of fin-clipped grilse in freshwater. Fish were fin-clipped as smolts at Camp Adams or Curventon.

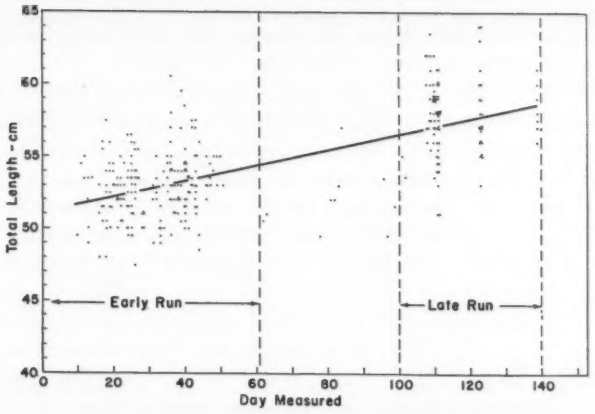

FIG. 6. Relation length and date of capture of unmarked grilse at Curventon counting fence. These fish belong to the same smolt class as those used in Fig. 4 and 5.

These small corrections do not alter the order of magnitude of the differences in length among the three samples. In both the early- and late-run samples, tagged grilse were shorter than fin-clipped grilse, which were in turn shorter than unmarked fish. Testing the significance of the differences between groups by the *t*-test gave the results in Table IV. For both tagged and fin-clipped fish, the means were significantly less than those for unmarked fish ($p = 0.01$ or less). The means for tagged fish were less than those for fin-clipped fish but the difference was only significant in the late-run group.

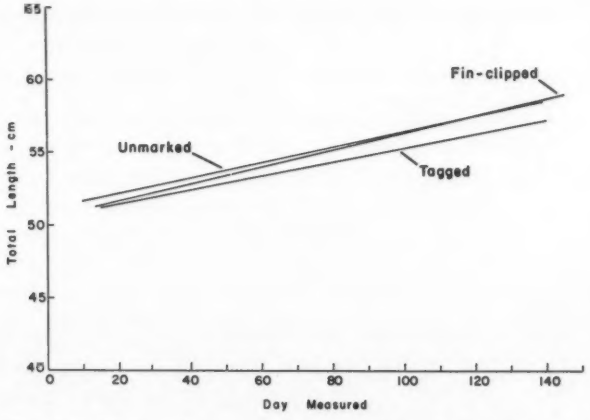

FIG. 7. Relations between length and date of capture among tagged, fin-clipped, and unmarked grilse. Lines of best fit are reproduced from Fig. 4, 5, and 6.

TABLE II. Mean lengths and dates of capture of early- and late-run components of tagged, fin-clipped, and unmarked grilse taken at the counting fence or by angling in the Northwest Miramichi.

	Early-run (day 0–61)		Late-run (day 100–140)	
	Mean date	Mean length (*cm*)	Mean date	Mean length (*cm*)
Tagged	30.2	52.0	115.1	56.1
Fin-clipped	31.9	52.4	118.2	57.4
Unmarked	31.1	53.0	115.3	57.7

TABLE III. Original and adjusted lengths of tagged, fin-clipped, and unmarked grilse in early- and late-run components of the samples. Adjustments based on differences in mean dates of capture and slopes of regression lines for entire samples.

	Early-run		Late-run	
	Original (*cm*)	Adjusted (*cm*)	Original (*cm*)	Adjusted (*cm*)
Tagged	52.0	52.1	56.1	55.3
Fin-clipped	52.4	52.4	57.4	57.4
Unmarked	53.0	53.0	57.7	57.9

TABLE IV. Results of *t*-tests comparing differences in length among tagged, fin-clipped, and unmarked grilse within early- and late-run components of samples.

	Early-run	Late-run
Tagged × fin-clipped	$p > .10$	$p < .05$
Tagged × unmarked	$< .01$	.01
Fin-clipped × unmarked	$< .01$	$< .001$

DISCUSSION

SURVIVAL

MARKED SMOLTS

Recovery rates of marked fish are influenced by such factors as survival, retention of marks, and recognition and reporting of marks. Differences in any of these may contribute to the varied recovery rates for the different groups of fish shown in Table I.

In the commercial fishery the recovery rates for grilse were much lower, whereas those for larger salmon were much higher, than at the fence. The

recovery rate for grilse in the commercial fishery was higher for tagged than for fin-clipped fish, whereas the reverse was true for larger salmon.

The low rate of recovery for grilse as compared with larger salmon reflects the low exploitation rate on grilse in the New Brunswick commercial fishery where the minimum legal mesh size of nets (5 inches, extension measure) is intended to prevent capture of grilse. In the offshore drift-net fishery, grilse are rarely taken. In the trap-net fishery in Miramichi Bay and in the estuary, although the nets generally allow grilse to pass through, grilse may be caught under some conditions, although they would not normally be landed.

The higher recovery rate for tagged than for fin-clipped grilse in the commercial fishery was probably because, in the trap-net fishery, grilse would only be seen or handled by the fishermen in the process of landing the larger salmon. Tags are much more conspicuous than clipped fins. Therefore, a smaller proportion of the fin-clipped than of tagged grilse would be recognized and reported. In the angling fishery, where each fish is usually carefully examined, the proportion of tagged to fin-clipped grilse does not differ significantly from that at the counting fence (Chi-square = 2.76).

The recovery rates for larger salmon were higher in the commercial fishery than at the counting fences apparently because the very high exploitation rate by the commercial fishery allows relatively few large salmon to survive to reach the counting fence. On these and other data it has been shown elsewhere (Allen and Saunders, 1967) that the commercial exploitation rate on these fish is well over 80%, and may be as high as 90%.

In comparing the recovery rates obtained with the two methods of marking, the main source of bias is avoided if the grilse taken in the commercial fishery are excluded. Including all the other groups, the ratio of the recovery rate for fin-clipped fish to that for tagged fish is, for grilse $\frac{604/16098}{133/5612} = 1.58$ and for larger salmon $\frac{290/16098}{39/5612} = 2.59$. Application of a chi-square test for second order interaction (Snedecor, 1946, p. 200) shows that these ratios differ significantly ($p = 0.02$).

The grilse data are based mainly on recoveries at the counting fence where all fish were carefully examined by trained staff; they are therefore thought to be unbiased. The large salmon data are based mainly on commercial fishery recoveries, and might therefore be expected to be biased against the fin-clipped fish, since these might be less efficiently identified by the fishermen than the tagged fish. Despite this, the ratio of the recovery rate for fin-clipped fish to that for tagged fish is much higher for larger salmon than for grilse. This suggests that the number of tagged fish not only diminishes more rapidly than that of fin-clipped fish, but that this difference continues to operate during the 2nd year of sea life. Continuing differential mortality and a continuing higher rate of tag loss than of fin-regeneration could both contribute to this effect.

Loss of tags at any stage could contribute to the apparent lower rates of survival of tagged than of fin-clipped and unmarked fish. If a tag were lost soon after being attached, it is likely that no detectable scars would be left on adult salmon and there is abundant direct evidence that tag losses occur. Adult salmon have been recaptured with tags about to fall off. Loose tags are occasionally found in gill-nets, presumably left there by salmon which escaped from the net. Personnel at the counting fences have examined salmon which appear to have lost tags recently. Thus, tag loss must account to some degree for the apparent low rates of recapture.

The 5376 unmarked grilse caught at the Curventon fence must have gone to sea as smolts in 1962 and it may be assumed, as an initial hypothesis, that at least the bulk of them had originated in the Northwest Miramichi above Curventon and had gone to sea without being marked. If it is possible to obtain an estimate of the number of these unmarked smolts, their approximate survival rate can also be determined. The very large number of unmarked grilse as compared with the marked ones suggests at first sight that the survival rate of the unmarked smolts must have been relatively high.

Virtually all the smolts captured at Camp Adams and Curventon in 1962 were either tagged or fin-clipped. However, many smolts escaped capture at one or both counting fences. No estimate of the efficiency of the Camp Adams fence is available, but one may be made for the Curventon fence which all the Camp Adams smolts must have passed on their way to the sea. Of 75 smolts tagged at Camp Adams and ultimately recaptured as adults, only 38 were intercepted as descending smolts at Curventon. The ratio 38/75 (= 51%) is an estimate of the efficiency of the Curventon fence. Since it is based on fish which survived and retained their tags until they returned as adults, it is not biased by mortality or tag loss. This is, however, an estimate of the efficiency of the Curventon fence during the time the Camp Adams smolts were passing it, and could be different from the average efficiency over the whole of the Curventon smolt run since efficiency can change from day to day because of fluctuations in water level, damage to the fence by freshets, etc. If this level of efficiency was maintained during the whole smolt run at Curventon, this fence caught only about 51% of the smolts passing it. On this basis, the estimated total number of smolts going to sea was 39,000, of which about 17,000 were unmarked.

Although this figure (51%) is an unbiased estimate of the efficiency of the Curventon trap during the period when the smolts trapped at Camp Adams were passing, it makes no allowance for the efficiency of capture of smolts passing Curventon at other times. In particular, it makes no allowance for smolts which passed before or after the period when the trap was operating, nor for any smolts which were so small at the time of migration as to pass freely through the screens of both fences. It must therefore be regarded as a high estimate of the overall efficiency of the Curventon trap, leading to an under-estimate of the total smolt run.

Fifteen years of study on the Miramichi system have produced no observations suggesting that large numbers of young salmon migrate when too small to be caught in the counting fences, or during the autumn after the fences have been removed, although such movements have been recorded in small coastal streams (Saunders, 1960; Meister, 1962). A substantial downstream migration past Curventon before the fence was installed in the spring seems to be entirely possible, particularly in 1962. In that year the fence began to fish on May 23, became fully operative on May 25, and smolts were caught in good numbers from the beginning. On that date the temperature had already risen to 16.2 C by day and 12.5 C at night. Elson (1962b) has shown that smolt migrations usually begin when the water has risen to 10 C. In 1951 when the trap was installed earlier, the run began on May 10 and three-quarters of the total run of 33,000 passed between May 16 and May 23 (R. A. McKenzie, personal communication). In the same year, L. R. Day and R. A. McKenzie (personal communication) caught 19 smolts in early April in fyke nets set in tidal portions of small brooks, tributary to the Miramichi estuary.

ESTIMATE OF THE 1962 SMOLT RUN

If 39,000 is thus an under-estimate of the 1962 smolt migration past Curventon, it is desirable to attempt to obtain a further estimate by a different method. This has been provided by Dr P. F. Elson (personal communication).

On the assessments of population density obtained by electric fishing in sample areas, Dr Elson estimates the mean density of large parr in the Northwest Miramichi above its junction with the Tomogonops as 16 per 100 yards^2 in the autumn of 1961. The productive rearing ground is estimated at 40 miles long with an average width of 25 yards. The estimated number of large parr in the autumn of 1961 was therefore about 282,000. The additional number below the Tomogonops, which is a source of base-metal mining pollution, was negligible. Judging from the pattern of heavy metal pollution in the first 4 months of 1962 (Sprague et al., 1965), smolt production from the lower part of the river can probably be disregarded. Survival from large parr in the autumn to the smolt stage has been 30–80% (Elson, 1957), with 40% being a fair average (Elson, 1962a). However, studies on the Pollett River (Elson, 1962b) have shown that under rather similar conditions, smolt production did not rise greatly above 5/100 yards^2 whatever the density of parr. On this basis, the maximum smolt production from the Northwest Miramichi in 1962 would have been about 90,000.

The number of smolts passing Curventon in the spring of 1962 has thus been estimated by different methods as a maximum of 90,000 and a minimum of 39,000. The corresponding estimates of the numbers of smolts which passed out unmarked are 68,000 and 17,000.

UNMARKED SMOLTS

If it is assumed that all the unmarked grilse which returned to the Northwest Miramichi in 1963 came from the above group of smolts, the survival rate

must lie between the limits of 8 and 31%. Even the lower of these figures is much higher than the survival rates estimated above for tagged and for fin-clipped Miramichi smolts. Since only those unmarked grilse taken at Curventon can be used in estimating their survival rate, the most valid comparison is with the rate of recovery at Curventon of the tagged and fin-clipped grilse. This is summarized in Table V.

TABLE V. Comparison of the numbers of tagged, fin-clipped, and unmarked fish passing downstream through the Curventon trap as smolts, and returning to it as adults.

Category	No. passing downstream	No. returning	Percentage returning
Tagged	5,612	110	2.0
Fin-clipped	16,098	532	3.3
Unmarked	17,000–68,000	5,376	31.0–8.0

Thus the minimum estimate of the survival rate of unmarked smolts to return to Curventon is four times that of tagged smolts and nearly two and one-half times that of fin-clipped smolts. It is also much higher than most of the estimates of the survival rate of marked smolts obtained in other experiments in Canada (Elson, 1957). One of the few exceptions are the data obtained in the Baltic Sea by Carlin (1959) where recovery rates of 30–40% were found. These, however, included a large proportion of fish caught as immature salmon in commercial fisheries in the open sea and not, as in the present case, only fish surviving to return to their native rivers.

Some of the marked smolts that lost their tags, or whose fin-clips became unrecognizable, probably survived to be counted as unmarked grilse on their return. Such disappearance of marks would increase the apparent difference in survival rate between marked and unmarked smolts by both diminishing the proportion of marked returns and increasing the proportion of unmarked returns. Although the extent of this effect cannot be assessed without an estimate of the proportion of marks disappearing, it is possible by pooling the data to eliminate its effect and obtain an overall estimate of the return rate as grilse to Curventon of all the smolts, marked and unmarked, leaving the Northwest Miramichi in 1962. The total return to Curventon was 6018 grilse from 39,000 to 90,000 smolts or 15.4–6.7%.

It is possible that some of the unmarked grilse counted at Curventon were not produced as smolts in the Northwest Miramichi but were strays from other rivers. However, this experiment and others using naturally produced smolts from the Northwest Miramichi have given few recaptures in other parts of the Miramichi system and none in other rivers (Elson and Kerswill, 1955; Saunders, 1967). Therefore, it is not likely that straying was a major cause of the apparently high survival rate of unmarked grilse.

It is not possible to examine similarly the survival rate of unmarked smolts returning as large salmon since scales were not read from all the unmarked large salmon taken at Curventon and it is therefore not known how many of these fish were derived from the 1962 smolt class.

GROWTH

These observations have provided an opportunity to study the effects of two different methods of marking on the growth of young salmon. Both tagging and fin-clipping caused some reduction in growth during part or all of the period between the smolt and grilse stages. Data were insufficient for a similar study of effects on salmon returning after longer periods in the sea.

Comparison with other data on the growth of Atlantic salmon in the sea (Allen et al., in preparation) suggests that the slopes of the regression lines of length against time provide estimates of the linear growth rate of grilse during the summer of return. The significant differences at the time of return between the lengths of tagged fish and of fin-clipped and unmarked fish are evidence of overall differences in the growth of these three classes between the smolt and grilse stages. The slopes of the regression lines during the summer of return are, on the other hand, not significantly different; this cannot be taken to indicate that tagging and fin-clipping were no longer affecting growth. The two groups showing the maximum difference are the tagged and unmarked fish. Assuming in each case that the mean smolt length was 14.0 cm (Forsythe, MS, 1967) their increments of growth in the sea and during return up to July 1 were 38.0 and 39.0 cm respectively. If their growth is equally affected by tagging during the whole of this period, their growth rates over any part of it are likely to have been approximately in the ratio of these increments, i.e. 1.000 to 1.026. Since the slopes of the regression lines are all between 0.048 and 0.059, the difference which would have to be detected is about 0.026×0.05, i.e. 0.0013. The standard errors of the estimates of the slopes range from 0.0023 to 0.0059. Thus, differences of the order of 0.0013 could not be detected, and it is therefore impossible with the present data to know whether or not the differences in growth rate, which brought about the observed differences in the size at return, were still continuing at the time of return.

OTHER MARKING STUDIES

Bergeron (1959) compared the growth in a hatchery of smolts tagged with Swedish-type tags and the growth of untagged smolts. Mean lengths increased from 14.5 cm in May 1958 to 25.1 cm for tagged and 25.5 cm for untagged fish in May 1959. Tagged fish were slightly lighter at the end of the experiment (150.4 g as compared with 152.9 g) and had suffered a higher mortality (17.0% as compared with 8.5%) than untagged ones.

In another hatchery study, Mills (1958) found that salmon parr carrying various types of tags attached through the base of the dorsal fin grew as fast as untagged fish during a period of 7 months. A. R. Murray (personal communication) found that any form of handling decreased the survival rate to

maturity of naturally produced smolts in a series of marking experiments in the Little Codroy River, Newfoundland.

In studies with other salmonids, Schuck (1942), Smith (1957), and DeRoche (1963) found that jaw tags adversely affect the growth rate of brook trout (*Salvelinus fontinalis*). Smith suggests that the tag which was attached to the mandible probably interfered with feeding. On the other hand, Armstrong (1949) using various fin-clip combinations on lake trout (*Salvelinus namaycush*) and Allen (1951) in tagging experiments with brown trout (*Salmo trutta*) found negligible effects of marking on fish growth. Pyle (1965) studied the effects of various kinds of tags on growth and swimming performance of brook trout. He found no difference in size or swimming performance 28 weeks after tags were attached.

Kelly and Barker (1963) found that redfish (*Sebastes marinus*) carrying Petersen tags on their opercula had slower growth rates than untagged fish and that this effect was measurable for 2½ years. They suggest as the most probable cause of decreased growth that the tag alerted their prey and thus helped them escape. Jensen (1966) reports that tagged spiny dogfish (*Squalus acanthias*) grew at about one-half the rate of untagged fish of about the same size. The growth rates of haddock (*Melanogrammus aeglefinus*) with Petersen discs attached to the operculum and "spaghetti" loops attached to the dorsum were reduced by 50 and 20% respectively (Jensen, 1963). On the other hand, Kohler (1963) and Jensen (1967) found little or no effect of various kinds of tags on the growth of Atlantic cod (*Gadus morhua*). Ricker (1949) and Coble (1967) found little or no effect of fin-clipping on the growth rates of spiny-rayed fishes.

It is concluded from the foregoing discussion that effects of various marking techniques on growth rate are influenced by such factors as species, size, migratory and feeding habits, and the type of mark used, but that Atlantic salmon at the smolt stage are particularly susceptible to adverse effects from tagging.

POSSIBLE CAUSES OF REDUCED GROWTH RATE OF MARKED FISH

In the present study the observed differences in length of returning marked and unmarked grilse could be caused by a temporary reduction in the growth rate of marked smolts during their early sea life. Power and Shooner (1966) showed that tagging small salmon (11–16 cm) in the estuary of the Nabisipi River, Quebec, had a temporary adverse effect on the growth rate. Growth was retarded for about 20 days. During this period the average daily growth increment, based on recaptures of tagged fish, gradually increased from about 0.2 to 0.7 mm which was considered close to the growth rate of undisturbed fish in the population. They report that normal behavior of young salmon was upset after tagging and that for several days after being released, the fish were not recaptured along with untagged juvenile salmon. After about 4 days tagged fish were again vulnerable to capture.

The first few months after smolts reach the sea is a period of very fast growth. Recaptures of marked smolts in the sea (P. F. Elson, personal communication) and results of laboratory experiments (R. L. Saunders, unpublished data) show that many smolts reach a length of 30 cm and a weight of 300 g by the end of August. In the laboratory, smolts doubled their weights between early May and late June and doubled their lengths between May and September. A temporary reduction in the growth rate during this period could possibly account for observed differences in size of returning marked and unmarked grilse. Tagging involves more handling of the fish than fin-clipping. Therefore, it is likely that tagging the highly delicate smolts would produce greater adverse effects than fin-clipping.

RELATION BETWEEN TIME OF SMOLT MIGRATION AND SIZE OF GRILSE

Since tagging was done near the beginning of the smolt run (Fig. 3), the tagged fish had a longer time in the sea, where the environment is favorable to rapid growth, than fin-clipped fish and could have tended to be larger than fin-clipped grilse at a given time of return. Moreover, it has been shown that the older Northwest Miramichi smolts (ages 3 and 4 as opposed to age 2) tend to migrate to sea earlier than the younger ones (Saunders, 1967) and that the earliest migrants from that river are larger than those leaving subsequently (Forsythe, MS, 1967). The size difference between early-migrating tagged smolts and late-migrating fin-clipped smolts was not maintained throughout marine life. Since the size trend reversed during a year at sea, i.e. fin-clipped grilse were larger than tagged ones (Fig. 7), the effect of tagging on the growth of the fish may be even more severe than that indicated by direct comparison of the sizes of tagged and fin-clipped grilse.

ACKNOWLEDGMENTS

We are grateful to Dr C. J. Kerswill, under whose guidance the Miramichi smolt and adult sampling facilities were developed. We thank Dr and Mrs J. H. Gee and Mr E. A. Chambers who helped tag smolts. Messrs E. J. Schofield, I. M. Jones, and W. G. Irving operated the counting fences. Drs M. W. Smith and P. F. Elson offered helpful suggestions for operation of counting fences and the preparation of this paper. Dr W. R. Knight and Mr J. K. Lindsey helped with statistical analysis of the data. The help given by Misses Marion Haley and Mary Holmes in cataloguing recapture data and by Messrs P. W. G. McMullon and F. P. Cunningham in preparing the illustrations is appreciated.

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Genetic Control in the Lakeward Migrations of Sockeye Salmon (*Oncorhynchus nerka*) Fry[1]

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ABSTRACT

Eggs of sockeye salmon taken from tributary, outlet, and beach spawners at Karluk, Alaska, were treated identically from time of egg fertilization through time of testing as fry in a laboratory. Test lots were released during the day and at night in a central release pool from which the fry could migrate either upstream or downstream through simulated stream channels. Oxygen-saturated water at 50 F (10 C) was pumped through the 40-ft (12.2-m) gravel-bottomed simulated stream at about 0.3 ft/sec (9.1 cm/sec).

Test results showed that directions (upstream or downstream) and times (day or night) of migration differed substantially between fry from the tributary and those from the outlet. Fry from beach spawning reacted in a manner similar to that of the tributary fry. These differences were concluded to be of genetic origin. The possible interaction of innate behavior and environment in controlling the migratory movements of salmonid fry is discussed along with the significance of choosing a donor stock with appropriate innate responses to make best use of a new environment.

INTRODUCTION

Lake-resident populations of salmonids often spawn in both tributary and outlet streams. Although the means and precision of homing to natal streams have been studied (Hasler and Wisby, 1951; Cope, 1957; Stuart, 1957; Lindsey et al., 1959; Hartman and Raleigh, 1964), the mechanisms by which the progeny are brought into the lake-rearing areas have received little attention. Obviously, fry from outlet streams and fry from tributary streams must differ in their response to currents if both groups enter the lake.

For fry of rainbow trout (*Salmo gairdneri*) from inlet and outlet streams at Loon Lake, British Columbia, Northcote (1962) postulated: "(1) *genetically distinct* outlet and inlet stocks each maintaining appropriate innate behavior responses which result in movement of young into the lake; (2) *genetically similar* outlet and inlet stocks responding to environmental differences between the streams which produce appropriate current responses and other behavior characteristics resulting in movement of young into the lake." A third explanation also appears possible: (3) *genetically distinct* outlet and inlet demes maintaining innate behavior responses which may be modified by the environment.

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J. Fish. Res. Bd. Canada, 24(12), 1967.
Printed in Canada.

Primarily on a theoretical basis, Lindsey et al. (1959) rejected the possibility of genetically distinct demes of rainbow trout at Loon Lake. Northcote (1962) thus centered his investigation on the effects of the environment. He concluded: "Differences in water temperature between Outlet and Inlet Creeks regulate differences in direction of migration through action on behavior associated with downstream movement, maintenance of position, and upstream movement." He found that fry moved downstream in cooler water, but upstream in warmer water and with sharp rises in water temperature.

In applying Northcote's findings to other species and field situations, I observed that emergent fry of sockeye salmon at Karluk Lake, Alaska, moved upstream at temperatures well below those published by Northcote; this movement did not necessarily accompany sharp increases in temperature. Also, sympatric demes of stream-spawning cutthroat trout (*Salmo clarki*) occur in certain tributaries to the St. Joe River in northern Idaho (Averett, 1962; MacPhee, 1966). Progeny of adfluvial cutthroat trout move downstream to the lake to feed and grow, whereas the progeny of upstream fluvial spawners remain in the stream. The same tributary may contain demes of cutthroat trout that maintain themselves above impassable falls. A persistent downstream migration of these fry under any environmental condition would eventually eliminate these demes. The rather similar environmental conditions encountered by all three demes of fry and their different reactions suggested behavior patterns under genetic rather than environmental control.

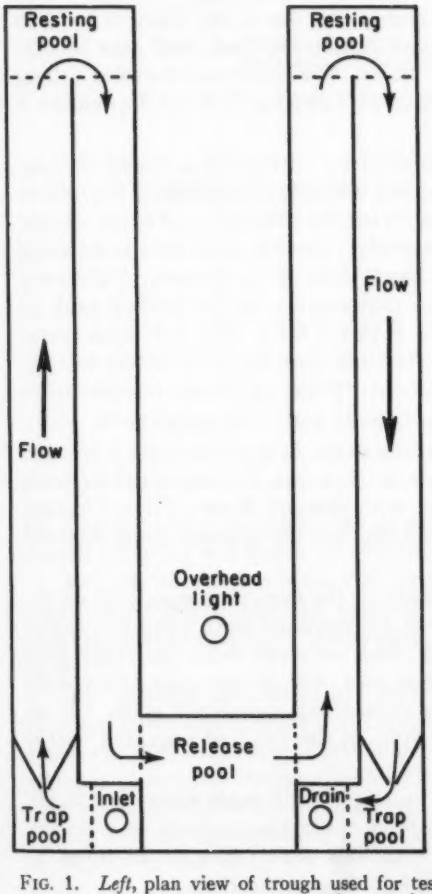
I theorized that fry migrating in the "wrong" direction in either a tributary or outlet stream could conceivably fail to survive and maintain the race. Fry emerging from a lake beach, however, would not be subject to the same forces of natural selection. Both upstream- and downstream-migrating individuals might be found within this group; it might be the gene pool from which the tributary and outlet demes originated. Loyd A. Royal stated (personal communication, 1965) that E. L. Brannon, of the International Pacific Salmon Fisheries Commission, found that emerging sockeye salmon fry gathered at the upstream end of a hatching trough if they came from a deme spawning below the lake, but that those from a lake tributary tended to collect at the downstream end of the trough. Fry from beach spawning at Cultus Lake tended to disperse without any consistent orientation. This behavior led me to include fry spawned in beach areas in the preliminary tests.

During the winter of 1965–66, I conducted laboratory tests with sockeye salmon fry from tributary and outlet streams of Karluk Lake, and from the lake beach, to test the null hypothesis that innate behavior did not control lake-oriented migrations of salmonid fry. I reasoned that if handling and environment were kept identical for "pure" demes of outlet, tributary, and beach fry, any significant differences in their lakeward migration would then be attributable to genetic differences.

METHODS AND MATERIALS

A "U"-shaped trough (Fig. 1) was constructed of plywood and sealed with fiberglass resin. It consisted of a central release pool that opened at each

end into a simulated stream channel. Each channel contained a small resting pool, which in turn opened into a second section of stream channels that doubled back alongside the first. These channels emptied into trapping pools. Oxygen-saturated water at 50 F (10 C) was pumped into the trough through a baffled plastic screen gate and circulated through the system as shown in Fig. 1. Two inches (5.08 cm) of water flowed over 1 inch (2.54 cm) of gravel through the stream sections. Water depths in the release pool and each of the two resting pools were 14.0 inches (35.6 cm) and 10.5 inches (26.7 cm), respectively. Water velocity of about 0.3 ft/sec (9.1 cm/sec) was maintained through the stream channels.



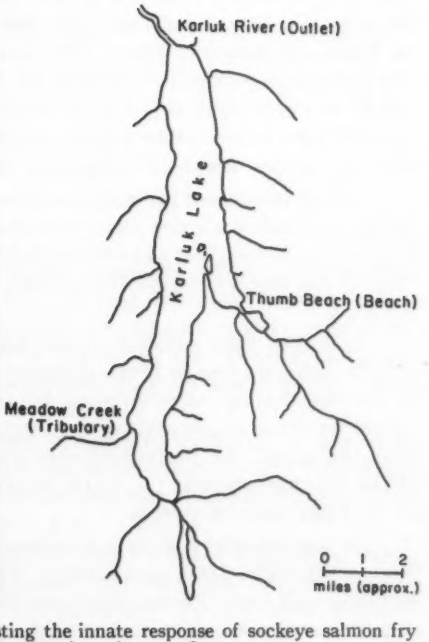


FIG. 1. *Left*, plan view of trough used for testing the innate response of sockeye salmon fry to a current. Arrows show direction of water flow.

FIG. 2. *Right*, spawning areas of the three donor demes of sockeye salmon at Karluk Lake on the northwestern part of Kodiak Island, Alaska.

The entire system was enclosed with black plastic sheeting to seal out exterior light. It was illuminated by a 60-w light bulb connected to an automated lighting system that simulated the gradual rising and setting of the sun and produced a day length of about 11 hr.

Eggs from three widely separated spawning areas of the Karluk Lake populations of sockeye salmon were selected for the study: Meadow Creek, a tributary to upper Karluk Lake; Thumb Beach, midway up the lake; and Karluk River at the lake outlet (Fig. 2). Hartman and Raleigh (1964) found that tributary homing of sockeye salmon at Karluk Lake ensured genetic separation. Eggs were collected on September 6, 1965, from each of the three groups of spawners; only fish actually engaged in spawning were taken. The eggs were fertilized and allowed to water-harden for 2 hr. They were then placed in plastic foam drip-type shipping containers, iced, and sent by air-freight to a fish hatchery at Lewiston, Idaho. The total time between taking eggs and putting them in hatchery trays at Lewiston late on September 6 was 15 hr.

Water at Lewiston hatchery is supplied by springs at a stable temperature of 50–52 F (10.0–11.1 C). Hatching was virtually completed by November 20 for the outlet deme, and by November 23 for the tributary and beach demes. The yolk sacs were absorbed by mid-December; the fish were then transferred 45 miles (72.4 km) for testing at the Small Animal Laboratory, University of Idaho, at Moscow, Idaho. The water temperature of the holding tank at the laboratory was maintained at 44–46 F (6.7–7.8 C). Test lots were transferred to water of 50 F (10 C) in an acclimation tank 48–72 hr before testing. Twenty-four hours before testing, two lots of 100 fish each were transferred to the test trough and held under test light levels and water conditions.

Paired releases of different combinations of fry originating from tributary, outlet, or beach spawning areas were made for each test. To distinguish between lots, one lot in each test was stained lightly with Bismark Brown Y dye (Deacon, 1961).[3] The test was repeated the following day, but the opposite group received the stain.

Both lots were released simultaneously in the central release pool of the trough and were free to move upstream or downstream. Both traps at the end of the test facility were emptied hourly. Fish removed from the traps were tallied by deme origin and by the direction and time of migration; they were then discarded. An individual test was considered completed when (1) all of the fish had entered the traps or (2) 90% of the fish had migrated within 24 hr from time of release.

To test the effect of time of release on migration I made releases at 0200, 0600, 1000, 1400, 1800, and 2200 hr. Three of the release periods were during darkness and three during daylight. Precautions were taken at all times to give identical treatment to both lots of fish in a test series.

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[3]The concentrations of stain (1:40,000) were weaker and exposure times (3 hr) shorter than those given by Deacon.

MOVEMENTS OF FRY

The first series of tests included all three demes of fry — tributary, outlet, and beach. The time and direction of migration of the Thumb beach fry did not differ significantly from those of the tributary fry. These results contrasted with the observations of E. L. Brannon cited earlier. But Thumb beach spawning is continuous with Lower Thumb tributary spawning at Karluk Lake, whereas no tributary spawning occurs at Cultus Lake. In the present study, samples taken from the Karluk Lake fry 1 month after hatching indicated a closer relation between the lengths of tributary and beach fry than between lengths of beach and outlet fry (Table I). Lengths of the tributary fry were

TABLE I. Length frequencies of sockeye salmon fry from representative samples of different origin.

Fork length (*mm*)	Origin of fry		
	Tributary	Beach	Outlet
26	5	3	–
27	5	5	–
28	10	11	1
29	6	9	4
30	3	2	12
31	1	–	7
32	–	–	6
Avg length	28.0	28.1	30.4

not significantly different from those of the beach fry ($P > .50$); lengths of both tributary and beach fry differed from those of the outlet fry ($P < .01$).

Because of the similarities in incubation time (noted earlier), migration, length distribution, and the proximity of spawning, the Thumb beach fry were assumed to be genetically similar to the tributary fry and were not tested further.

The primary purpose of the tests was to compare directions of migration between outlet and tributary fry, and to examine the effect of light and release time on time of migration. Three major differences were found in the migratory patterns of the two demes (Tables II and III).

In the time allotted for the test, 98% of the tributary fry moved downstream, 1% moved upstream, and 1% did not enter the traps. The corresponding values for the outlet fry were 66%, 30%, and 4%. The direction of movement thus differed significantly between demes. The percentage of tributary fry that moved upstream and the percentages of both groups that did not move were negligible.

TABLE II. Cumulative counts of sockeye salmon fry in traps, from paired releases of 100-fish test lots; fish in one lot of each release were stained.

Release time (*hr*) and group stained, each release	Outlet fry					Tributary fry				
	Movement					Movement				
	Upstream		Downstream			Upstream		Downstream		
	Day	Night	Day	Night	Not trapped	Day	Night	Day	Night	Not trapped
0200 Outlet	30	12	21	35	2	0	2	1	96	1
Tributary	16	25	14	41	4	0	6	2	90	2
0600 Outlet	12	32	8	45	3	0	0	1	99	0
Tributary	5	24	7	57	7	0	0	1	98	1
1000 Tributary	28	2	59	11	0	0	0	1	99	0
Outlet	28	0	11	55	6	0	0	16	82	2
1400 Tributary	8	2	50	38	2	0	0	20	80	0
Outlet	7	0	47	44	2	1	0	18	81	0
1800 Tributary	36	9	47	8	0	0	0	8	92	0
Outlet	14	23	49	11	3	0	0	1	97	2
2200 Tributary	1	21	7	61	10	1	0	0	98	1
Outlet	1	21	4	63	11	0	3	1	94	2
Total:	186	171	324	469	50	2	11	70	1106	11
Percentages:	15.50	14.25	27.0	39.08	4.17	0.17	0.92	5.83	92.17	0.92
	29.75		66.08			1.09		98.00		
	Day 42.50		Night 53.33			Day 6.00		Night 93.09		

TABLE III. Summary of pertinent results from analysis of variance of data in Table II.

Source to	Outlet fry, significance at 0.01	Tributary fry, significance at 0.01
Direction	S.	S.
Light condition	N.S.	S.
Direction × light	N.S.	S.
Light × release time	S.	N.S.

Only 6% of the tributary fry moved into the traps during daytime, whereas 93% moved at night; however, 42.5% of the outlet fry moved into traps during the day and 53.0% at night. Presence or absence of light did not significantly

affect the time of movement of the outlet fry, but did affect that of the tributary fry (Table II). Hourly catch records confirmed that the fish started to move on the day or night after release. Most movements of tributary fish occurred during the first 2 hr of darkness. The interaction between release time and light condition confirmed that outlet fry migrated both day and night according to time of release, but that nearly all tributary fry migrated at night regardless of when they were released.

The staining process used to distinguish between test lots had no detectable effect on migration.

The tests demonstrated that the outlet and tributary fry differed significantly in their direction of migration and time of movement. Because handling was identical, these differences evidently were innate. The null hypothesis stated earlier was therefore rejected.

POSSIBLE EFFECT OF LENGTH DIFFERENCES

The tributary fry were 2 mm shorter in average fork length than the outlet fry (Table I). The question arises of the possible effect of this difference in size on the success of upstream movement and consequently on the results of the test.

Information on the swimming ability of salmonid fry 32 mm or less in length is limited. Kerr (1953) found that wild juvenile chinook salmon (*O. tshawytscha*) 30–59 mm long could maintain position in a test flume for 10-min exposures in velocities between 1.0 and 1.5 ft/sec (30.48 and 45.72 cm/sec) and for 1 hr at velocities of 1.0–1.2 ft/sec (30.48–36.58 cm/sec). These wild chinook salmon fry thus withstood velocities 3–5 times higher than the smaller sockeye salmon fry in the present tests. I do not believe the swimming ability of sockeye salmon fry is so much poorer than that of chinook salmon fry that it was a significant factor in the low velocity (9.1 cm/sec) of the present tests.

Measurements indicated that about two-thirds of the tributary fry were within the length range of the outlet fry (Table I). Even if length were a controlling factor in upstream migration, one would expect a much higher percentage of upstream movement by tributary fry than was actually recorded. Length cannot be entirely eliminated as a limiting factor on upstream movement, but I do not consider it of consequence in the present tests because it can hardly account for the consistent and significant separations attained.

RELATION OF TEST RESULTS TO MIGRATION AT KARLUK LAKE

The proportion of fry from tributary or outlet demes moving upstream or downstream during the tests should not be construed as an accurate estimate of natural migration in either direction. The experimental trough was only 40 ft (12.2 m) long and a fish that strayed 20 ft (6.1 m) in either direction from the central release pool was trapped and removed. The salient feature of the laboratory test is that even within this short distance, fry from the two demes consistently and significantly differed in patterns of migration.

Table IV, which shows the results of a limited fry-trapping study at the outlet of Karluk Lake in 1958, is perhaps more indicative of natural movements of fry in the stream than are laboratory tests.

TABLE IV. Routes and direction of migration of sockeye salmon fry in the Karluk River in 1958.[a]

Date	Trapping site and distance from bank	Upstream catch/hr	Downstream catch/hr
April 12–14	East bank, 0–3 ft (0.0–2.7 m)	71.4	2.2
8–11	" 3–6 ft (2.7–5.5 m)	13.9	8.9
8–11	Midstream	0.5[b]	1.8
23–26	"	0.2[b]	3.5
18–19	West bank, 0–3 ft (0.0–2.7 m)	177.0	8.4

[a]The fry migration up Karluk River into the lake in 1958 was almost completed by late May. In diminishing numbers, however, a few young of the year were still moving upstream until August when the last visual observation was made. These stragglers may represent the upstream migration of a portion of those fry swept downstream by the current or may represent a group of fry that normally spend a growing period in the river.

[b]Fry captured moving upstream in midstream were probably able to do so only because the trap created an area of relatively quiet water immediately below it.

POSSIBLE MECHANISMS THAT CONTROL MIGRATION

That fish are sensitive to changes in temperature is well documented. Bardach and Bjorklund (1957) found the level of temperature discrimination to be about .05 C or less. Salmonids apparently tend to move upstream toward the headwaters and tributaries to avoid temperatures that rise above the preferred range. Likewise, they tend to move downstream out of some tributaries into deeper water to avoid extremely low temperatures during winter. High or low temperatures could elicit these responses in emergent salmonid fry, therefore, as observed in rainbow trout fry in Loon Lake by Northcote (1962) and thus affect their lakeward migrations as postulated in Fig. 3. The differences in temperature between outlet and tributary streams (as discussed by Northcote, 1962) would tend to increase or to reinforce the inherent patterns of lakeward migration, but temperature extremes may eventually override the inherent patterns.

The controlling stimuli may possibly vary between species and environments: i.e., temperature at Loon Lake, innate behavior at Karluk Lake. Young salmonids may receive other directional stimuli as well as those already found. For example, the lake may contribute an attracting substance into the outlet stream that is absent in the tributaries; or the presence of lake food organisms in the outlet stream may attract the outlet fry upstream. It is postulated that the ultimate direction of migration is determined by the summation of both extrinsic and intrinsic stimuli.

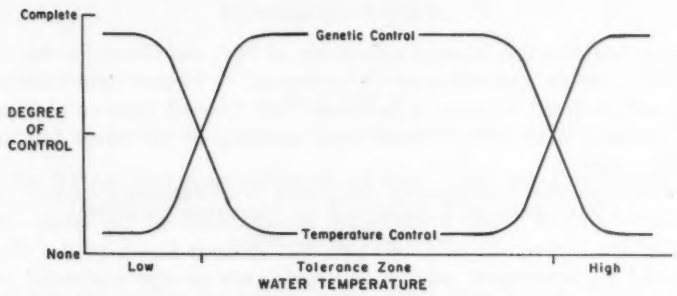

FIG. 3. Theoretical interaction between temperature and genetics in controlling the direction of migration of salmonid fry.

From time to time attempts are made with variable success to establish stocks of fish in new areas or to bolster depleted stocks by transplants of eggs or fry. A. M. R. Burnet (personal communication, 1966) planted rainbow trout eggs from a lake population into a New Zealand stream; downstream movement of fry and fingerlings was later observed at a fish trap. The trapped fry made up 5% of the number of eggs planted, and there was no evidence of the establishment of a resident population. Later, when eggs from a stream population were planted, no downstream migration of fry or fingerlings was observed, and a population was established in the stream.

Attention has been focused recently on the importance of matching the characteristics of the donor population to the requirements of the environment to be seeded. There is now reason to believe that inherent migration tendencies of emergent fry may significantly influence the success or failure of a planting attempt and must be considered in the selection of an exotic stock for an area. Obviously, either tributary or outlet populations could meet the requirements if environment alone controlled the migration. But when innate migration patterns are involved, plantings are more likely to succeed if the innate behavior as well as the environment of the donor is matched to the new environment.

SUMMARY AND CONCLUSIONS

1. During the winter of 1965–66 the response to current of outlet, tributary, and beach demes of sockeye salmon fry from Karluk Lake, Alaska, were tested in a laboratory. Handling and environment were identical from time of egg fertilization through testing.

2. The test results demonstrated that outlet and tributary fry differed significantly in their direction and time of migration. Because the environment was kept identical these differences were concluded to be of genetic origin.

3. The results of my study together with those of a study by Northcote (1962) on rainbow trout imply that the direction of migration of salmonid fry may be caused by: (*a*) environmental control (Northcote, 1962); (*b*) innate behavior (present study); or (*c*) a combination of intrinsic and extrinsic factors.

4. Innate patterns of migratory behavior may significantly affect the success of an egg or fry transplant and therefore should be considered in choosing a stock of fish for planting in a new environment.

ACKNOWLEDGMENTS

I wish to thank the Idaho Department of Fish and Game for use of hatchery facilities and for assistance by the personnel — Messrs Paul Cuplin, James Dayley, and Richard Martin, in particular. Mr Darrell Farmen of Anchorage, Alaska, assisted with the collection and handling of the adult fish and eggs at Karluk Lake.

The constructive criticisms of Drs Craig MacPhee and Donald Chapman of the University of Idaho contributed substantially to the study. Dr Dale Everson of the University of Idaho and Mr William Davis of the Bureau of Commercial Fisheries gave advice and assistance on the statistical analysis.

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NOTES

In Vitro Susceptibilities of the Lobster Pathogen *Gaffkya homari* to Various Disinfectants and Antibiotics

Periodically, serious economic losses result from outbreaks of gaffkemia, the fatal disease of lobsters caused by *Gaffkya homari* (Snieszko and Taylor, 1947; Hitchner and Snieszko, 1947; and Roskam, 1957). The occurrence of epizootics of this disease among captive lobsters in Europe and North America has been cited previously (Rabin, 1965; Stewart et al., 1966). No effective means for combatting this disease has been reported.

Therapeutic measures involving antibiotics have not been developed; in fact, the susceptibility of the infective agent has been determined only for streptomycin, penicillin G, aureomycin, and polymixin (Aaronson, 1956). In addition no adequate information is available on the effectiveness of various disinfectants for cleaning the holding facilities after disease outbreaks. When studies on gaffkemia were initiated in this laboratory the need for information on which to base therapeutic and preventive measures became apparent. Accordingly we have determined the susceptibilities of several strains of *G. homari* and one strain of *G. tetragena*, the only other member of this genus, to several commercially available disinfectants and to a series of antibiotics.

Test organisms.— The bacteria used in the tests included *G. homari* ATCC 10400, three *G. homari* strains isolated at this laboratory and designated FRB 1, FRB 21, and FRB 22, and one strain kindly given by Dr H. Rabin of the Department of Pathobiology, School of Hygiene and Public Health, The Johns Hopkins University, Baltimore, Maryland and designated Rabin's strain. *Gaffkya tetragena* ATCC 10875 was included for purposes of comparison.

Disinfectant tests.— The following modifications to the Chick-Martin test outlined by Sykes (1958) were used to compare the relative effectiveness of the disinfectants: (1) *G. homari* and *G. tetragena* as the test organisms; (2) substitution of 5% Bacto[1] yeast extract at *p*H 7.0 for the British Standards Institution yeast; (3) Bacto brain heart infusion broth (BHI) in place of the standard medium; (4) growth at 27 C rather than 37 C; (5) transfer of 0.05 ml of inoculum for subculture by pipette rather than by a standard loop; and (6) neutralization of the disinfectant at the end of the contact time. Neutralization (Davies, cited by Sykes, 1958) was achieved by transferring, at the end of the 30-min contact period, 1 ml of the disinfectant–bacteria mixture to 5 ml of 1% Tween 80[2] (polyoxyethylene sorbitan monooleate) in distilled

[1]Difco Laboratories Inc., Detroit, Mich.
[2]Nutritional Biochemicals Corporation, Cleveland, Ohio.

J. Fish. Res. Bd. Canada, 24(12), 1967.
Printed in Canada.

water. The use of a neutralization step involving Tween 80 was necessary in order to obtain consistent results with the quaternary ammonium based formulations. This mixture was shaken vigorously with six small glass beads for 1 min and allowed to stand; 0.05 ml was then subcultured. Exactly 6 min elapsed between the end of the contact time and subculturing. The neutralization step was omitted for testing calcium hypochlorite. Freshly distilled phenol as reference material was subjected to the same treatment as the disinfectants in both neutralized and non-neutralized samples.

The susceptibilities of the two species to the disinfectants, although not precisely equal, are in the same general range (Table I). In the series

TABLE I. Lethal concentrations[a] of disinfectants.

Disinfectant	Test organisms	
	G. homari ATCC 10400	*G. tetragena* ATCC 10875
Non-neutralized		
Phenol	2.64	2.64
$Ca(OCl)_2$[b]	2.0	1.32
Neutralized (Davies, 1949)		
Phenol	2.03	2.03
Blue Grotto[c]	0.165	0.146
Roccal[d]	0.014	0.020
Teramine[e]	0.013	0.018
Weladyne[f]	0.146	0.146

[a]Expressed as per cent (w/v) of original disinfectant preparation (concentration of active material in original solution given in parentheses after supplier's address below).
[b]Fisher certified reagent. Fisher Scientific Company, Fair Lawn, N.J.
[c]Cody's Limited, Halifax, N.S. (41.7%).
[d]Winthrop Chemical Co. Inc., New York 13, N.Y. (10%).
[e]West Chemical Products Ltd., Montreal, Quebec (10%).
[f]West Chemical Products Ltd., Montreal, Quebec (37.7%).

of tests in which the neutralization step was included, the concentration of phenol required to kill all of the organisms was reduced. This reduced requirement is consistent with the emphatic statement of Sykes (1958) that any change in a disinfectant test procedure will alter the results significantly. Obviously an assessment of the disinfectants under actual field conditions is essential to determine their true effectiveness. These data, however, do give an indication of relative effectiveness and aid in making a choice between various disinfectants and their useable concentrations. These disinfectants are commonly available and since they are effective at low levels even in the presence of an appreciable amount of organic matter they should be useful

TABLE II. Sensitivities[a] of *Gaffkya* species and strains to various antibiotics.

Antibiotic	Concentration	*G. tetragena* ATCC 10875	*G. homari* ATCC 10400	*G. homari* Rabin	*G. homari* FRB 1	*G. homari* FRB 21	*G. homari* FRB 22
Single disc method							
Bacitracin	10 units	S 18	S 22		S 24	S 30	S 30
Carbomycin	15 mcg	S 23	S 22		S 30	S 25	S 25
Dihydrostreptomycin	2 mcg	MR 8	R–		MR 10	R –	R –
Elkosin	1 mg	R –	R –		R –	R –	R –
Erythromycin	15 mcg	S 26	S 22		S 31	S 30	S 37
Furacin	100 mcg	S 20	R –		S 31	R –	R –
Furadantin	100 mcg	S 23	S 14		S 26	R –	S 15
Furamazone	100 mcg	S 25	S 19		S 22	R –	R –
Furoxone	100 mcg	S 18	R –		S 22	R –	R –
Gantrisin	2 mg	R –	R –		R –	R –	R –
Kanamycin	30 mcg	S 19	S 15		S 20	S 15	S 15
Kynex	1 mg	R –	R –		R –	R –	R –
Mandelamine	3 mg	S 21	S 15		S 20	R –	R –
Nystatin	100 units	R –	R –		R –	R –	R –
Oleandomycin	15 mg	S 24	S 22		S 26	S 30	S 32
Ristocetin	30 mcg	S 13	S 18		S 22	S 26	S 25
Sulfaethylthiadiazole	1 mg	R –	R –		R –	R –	R –
Sulfathiazole	1 mg	R –	R –		R –	R –	R –
Tetracycline	30 mcg	S 26	S 24		S 30	S 32	S 35
Thiosulfil	1 mg	R –	R –		R –	R –	R –
Double disc method							
Ampicillin	2 mcg	S 30	S 30	S 30			
	10 mcg	S 35	S 35	S 35			
Aureomycin	5 mcg	S 30	S 25	S 25			
	30 mcg	S 35	S 30	S 30			
Chloromycetin	5 mcg	S 20	S 20	S 18			
	30 mcg	S 30	S 30	S 30			
Coly-Mycin	2 mcg	–	R –	R –			
	10 mcg	S 25	R –	R –			
Demethchlor-tetracycline	5 mcg	S 25	S 25	S 25			
	30 mcg	S 30	S 30	S 30			
Neomycin	5 mcg	S 20	S 12	S 12			
	30 mcg	S 30	S 18	S 18			
Novobiocin	5 mcg	S 20	S 20	S 20			
	30 mcg	S 30	S 30	S 30			
Oxacillin	1 mcg	S 30	R –	R –			
Penicillin	5 units	S 30	S 30	S 30			
	10 units	S 35	S 35	S 35			
Polymixin B	50 units	S 25	–	–			
	300 units	S 30	S 18	S 15			
Streptomycin	2 mcg	S 17	R –	R –			
	10 mcg	S 20	R –	R –			
Terramycin	5 mcg	S 30	S 30	S 30			
	30 mcg	S 35	S 35	S 35			
Triple sulfa	0.25 mg	R –	R –	R –			
	1.0 mg	R –	R –	R –			
Vancomycin	5 mcg	S 17	S 20	S 20			
	30 mcg	S 22	S 25	S 25			

[a]Sensitivity (S – susceptible; MR – moderately resistant; R – resistant) followed by inhibition zone diameters in millimeters.

in disinfecting lobster storage units. Calcium hypochlorite has been used already to a limited extent for this purpose (Goggins and Hurst, 1960).

Antibiotic tests.— The inoculum for the single disc tests, 0.05 ml of a 24-hr BHI broth culture, was spread evenly over the surface of a BHI agar plate (100 mm diam, 10 ml agar). The antibiotic discs[3] were pressed on the agar surface and the plates were incubated at 28 C. The full diameters of the inhibition zones were measured in millimetres after sufficient growth had occurred, between 24 and 48 hr depending upon which *G. homari* strain was being examined. An additional set of antibiotics was tested at two different strengths using Oxoid[4] sensitivity test agar (15 ml) plates.

The majority of the *Gaffkya* strains were sensitive to most of the antibiotics but not to the sulfa compounds (Table II). *Gaffkya tetragena's* sensitivity differed slightly from those of the *G. homari* strains chiefly with regard to streptomycin and oxacillin. This finding is in contrast to the results of Aaronson (1956), who showed that *G. homari* ATCC 10400 and strain S-I were inhibited by streptomycin, an unimportant difference since similar discrepancies between the *G. homari* strains themselves were noted (Table II). In vivo tests utilizing these results will now be carried out to determine which antibiotic is most effective against the disease.

The authors gratefully acknowledge the technical assistance of Mrs B. M. Zwicker and Miss J. F. MacDonald.

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Received for publication July 14, 1967.

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[3]Baltimore Biological Laboratory, Baltimore, Maryland.
[4]The Oxoid Division of Oxo Ltd., London, England.

Breeding King Crabs *Paralithodes camtschatica* Located in Ocean Environment[1]

King crabs, *Paralithodes camtschatica* (Tilesius), of the north Pacific follow yearly migration patterns. In late winter they move to waters of less than 40 fath on breeding migrations (Marukawa, 1933; Powell, 1964). The inshore areas of the Kodiak-Afognak Island group provide a suitable environment, wherein molting and breeding occur (Wallace et al., 1949). On the breeding grounds females are selected and grasped by males as described by Powell and Nickerson (1965). A male king crab will release its partner only after she has molted and subsequently bred.

Since king crabs utilize inshore shallows for breeding, it seemed probable that they were simultaneously occupying ocean banks of the Kodiak area. Portlock Bank and Marmot Flats (Fig. 1), defined by outside isobaths

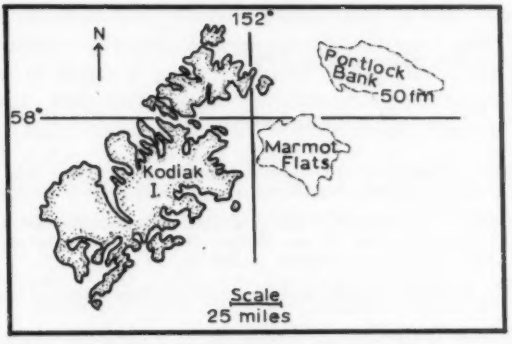

FIG. 1. Geographical locations of Portlock Bank and Marmot Flats.

of 50 fath, are located northeast of Kodiak Island on the edge of the continental shelf. These ocean shallows were the sites of investigative otter trawling operations during April and May of 1966 (McMullen, 1967) and 1967 (J. C. McMullen, 1967, unpublished ADF&G data). Standard 400-mesh eastern otter trawls were fished at 21 and 59 different stations on Portlock Bank and Marmot Flats, respectively.

A total of 3181 king crabs were captured on Portlock Bank in 1966 and 7668 crabs were caught on Marmot Flats the following year.

Nine grasping pairs of king crabs were caught on Portlock Bank. Males continued to grasp their partners after removal from the trawl. A total of

[1]This investigation was conducted with Federal-Aid under the Commercial Fisheries Research and Development Act of 1964 (P.L. 88-309).

J. FISH. RES. BD. CANADA, 24(12), 1967.
Printed in Canada.

2152 females were also caught; 686 had recently undergone ecdysis, and 1466 were approaching ecdysis. Six different tows collected about 75 shed king crab exoskeletons.

Sixteen grasping king crab pairs were caught in 10 different trawls on Marmot Flats. A total of 5837 mature females dominated the catch. The number of recently molted females captured was 264. Nine very new-shell females had spermatophore bands spread around their oviducts. Empty king crab exoskeletons were collected in two tows.

Capture of 25 king crab grasping pairs strongly indicates that king crabs breed on Portlock Bank and Marmot Flats. The presence of new-shell females with spermatophore bands spread in the vicinity of their oviducts also indicates that offshore breeding takes place. The abundance of females in various molt stages during their breeding season and the presence of shed exoskeletons in the trawl collections provide further evidence that king crabs probably molt and breed in an ocean environment.

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Received for publication September 6, 1967.

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Cuspidaria cowani, a New Septibranch Mollusc from the Northeastern Pacific

On October 17, 1966, while dredging off the southern Queen Charlotte Islands, two living specimens and one shell fragment of a new species of *Cuspidaria* (s.s.) were collected from 1318 m in a Digby-type scallop dredge provided with a ¼-inch nylon liner. The substrate consisted of small cobbles, gravel, and fine mud.

Cuspidaria (*Cuspidaria*) *cowani* sp.nov.

Diagnosis.— Large for the genus, subventricose, right valve slightly the smaller, inequilateral. Shell thin, white, surface chalky with patches of thin, brown dehiscent periostracum. Sculpture consisting of fine incremental striae only. Rostrum tubular, straight, approximately half total shell length. Lateral plication at base of rostrum present in left valve. Umbo inflated, incurved. Ligament internal, with lithodesma. Interior glossy. Single strong posterior lateral tooth in right valve; left valve edentulous. Narrow chondrophore identical in each valve. Muscle scar slight.

Type locality.— Fisheries Research Board Station 66-70, off Moresby Island, Queen Charlotte Islands, British Columbia, at 52°30′N lat and 131°55′W long. Depth 1318 m.

Type specimens.— The holotype has been deposited in the National Museum, Ottawa, Mollusc Type Collection Catalogue No. 45651. The paratype is in the University of British Columbia Cowan Collection No. 7170.

Dimensions (in mm) are as follows:

	Length	Width	Height	Length of rostrum
Holotype	29	11	9	14
Paratype	28.5	12.5	10.5	13.5

Comparison.— The species is readily distinguished from other Northeastern Pacific *Cuspidaria* by the greater proportional length of the rostrum. *Cuspidaria cowani* is allied to the Japanese *Cuspidaria suganumai* Nomura but can be differentiated by the thinner and less-inflated shell. *Cuspidaria cowani* is similar to the Northwestern Atlantic *C. rostrata* Spengler, but in this species the rostrum is curved ventrally and the concentric growth lines are more prominent.

J. Fish. Res. Bd. Canada, 24(12), 1967.
Printed in Canada.

The species is named for Dr I. McTaggart-Cowan, Dean of Graduate Studies, University of British Columbia, in recognition of his prominent activity in Western Canadian malacology.

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Received for publication August 2, 1967.

(FIG. 1–3 *opposite*)

FIG. 1–3. *Cuspidaria cowani* sp.nov.

Bernard — J. Fish. Res. Bd. Canada

Records of the Atlantic Walrus, *Odobenus rosmarus rosmarus*, from Newfoundland

The southern limit of the Atlantic walrus range has been retreating northward since the last Pleistocene glaciation, the process being hastened greatly in historic times by the predation of man (Dunbar, 1949). The Pleistocene distribution has been documented by Davies (1958), and Manville and Favour (1960) have further considered southern distribution in the Pleistocene and in historical times. According to Mansfield (1963), breeding herds occurred as far south as Sable Island and the Magdalen Islands from which places they were exterminated by the end of the eighteenth century.

The present distribution has been documented at length by Loughrey (1959); the walrus is now restricted to the Arctic and only occasional strays occur in the Maritime Provinces of Canada. King (1964) has reviewed historical distribution and extralimital occurrences of the species in Europe. Arctic extralimital records have been dealt with by Harington (1966).

Records of recent extralimital strays of the species from Newfoundland are presented in this note.

New Newfoundland records.— On February 24, 1967, a walrus was reported in the harbour of Bay Bulls on the southeast coast of Newfoundland. (Loose patches of arctic ice extended southwards to the Baccalieu Island area on February 19.) When the author arrived late in the morning the animal was hauled out on an old wharf cribbing. Residents reported that it was first sighted there at about 0700 hr and remained the entire day save for a ½-hr excursion into the water. At high tide the following morning residents saw the animal haul out on a nearby wharf; there it remained until February 26 when it was pushed back into the water. It was seen swimming in the harbour for a few hours after which time it disappeared from the area.

The author observed the animal from the shore on February 24 and was able to examine it from within a few feet the following day; several photographs were taken.

The specimen (Fig. 1) was a young bull with an estimated weight of 700 lb. The tusk lengths were estimated at 6–7 inches. A wound, which appeared to be superficial, was noted in the left axilla; this was probably caused by climbing over rocks. The outline of the pelvic girdle was quite prominent, indicative of an emaciated condition.

Two further walrus sightings were made in Newfoundland during the winter of 1967. Fishermen sighted a large specimen at Champney's, Trinity Bay, on March 25, and on April 1 seal hunters spotted a large walrus on a pan of ice about ½ mile from Horse Chops (Staff Newsletter, Canada Department of Fisheries, April 1967). These two reports likely refer to the same specimen since the localities and dates are so close.

J. Fish. Res. Bd. Canada, 24(12), 1967.
Printed in Canada.

FIG. 1. Young bull walrus ashore at Bay Bulls, February 26, 1967.

Other records from Newfoundland may be noted. The St. John's *Evening Telegram* of February 16, 1949 reports that, during the previous week, a walrus was shot by bird hunters in the vicinity of Cape John.

In July of 1949 an old carcass was found at Hare Bay, Fogo Island; it had drifted ashore and was not killed in the area (Fisheries Research Board of Canada, 1952; the specimen was examined by Mr A. M. Fleming). Because the head had been mutilated and the tusks removed, the carcass was identified from the baculum.

Mr Farley Mowat reports (personal communication) collecting a skull on the beach at Cow Head, on the Newfoundland west coast, in 1964.

Gilpin (1870) described a large bull shot in the Stait of Belle Isle in March of 1869. Reeks (1871) reported a specimen "driven ashore" in St. George's Bay in the late 1860's. He also alluded to the frequent occurrence of walrus bones along the Newfoundland coast. In this regard the St. John's *Evening Telegram* of February 23, 1949, carried the following article (referring to the walrus reported in the February 16th edition):

"The walrus shot lately up toward the tip of northern Newfoundland was an interesting item of news and it is apparently a fact that the creatures in the past were quite common in the northern parts of the country, at least.

"So far as we know none of the animals has been seen inh tis bay for a good many years but their tusks have been picked up on this side of the bayshore, the discovery helping to prove that they at one time resorted in these waters. It is understood that the tusks of the animals are like that of the elephant. One picked up on this shore some twenty-odd years ago was seen by your correspondent, and it was considered quite a curiosity locally."

Discussion.— Walruses are known to have inhabited the island of Ramea, but were exterminated there before the end of the 18th century. It is obvious from the accounts of Cartier's 1534 cruise (Biggar, 1924; Baxter, 1906) and the writings of Hakluyt (1958–1600), that references to Ramea do not relate to Ramea Island off the Newfoundland southwest coast but rather to Brion Island, one of the Magdalen group — not Sable Island as Allen (1880) suggests.

In recent years two papers dealing with Canadian Atlantic extralimital occurrences have appeared. Wright (1951) recorded a large bull shot at Bear

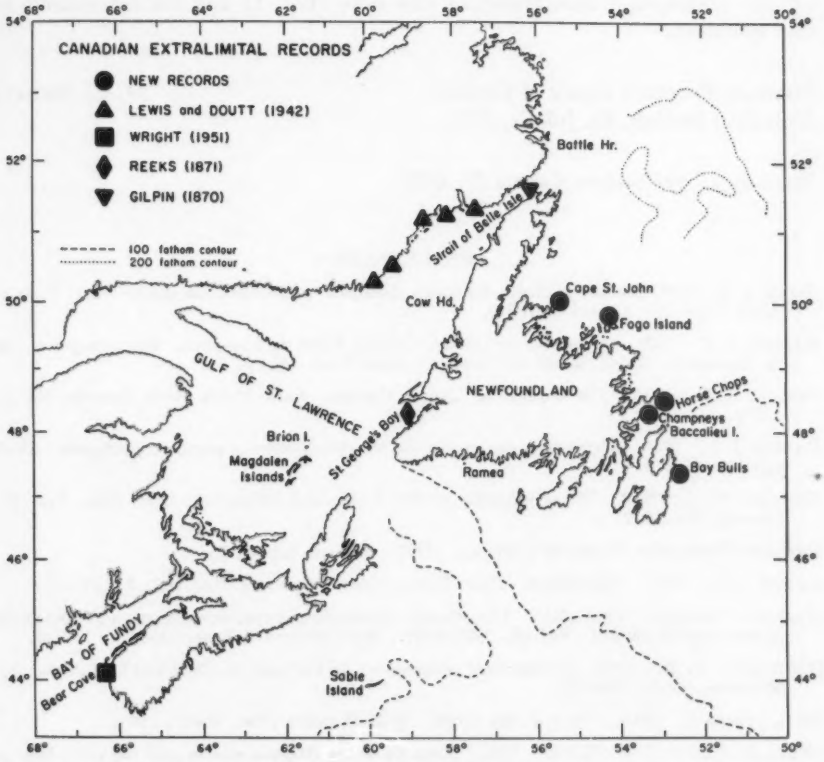

FIG. 2. Map showing recent Canadian extralimital records of the walrus and place names mentioned in the text.

Cove, near the mouth of the Bay of Fundy, on April 27, 1937. In a paper based upon interviews with inhabitants of Saguenay County, Quebec, Lewis and Doutt (1942) recorded five occurrences of walruses in the northern part of the Gulf of St. Lawrence. These were sighted or shot during the months of December ca. 1910, May ca. 1915, April 1917, July 1932, and June 1934.

This appears to be the first published account of walruses from Newfoundland since that of Reeks (1871) although undoubtedly many unrecorded strays have visited the area, probably moving south with the winter pack ice. All known recent Canadian Atlantic extralimital records are plotted in Fig. 2. It is interesting to note that 7 of these 12 records are attributed to bulls, at least 3 of which were subadult. None of the sexed specimens were females.

I wish to thank Dr W. Templeman and Mr A. M. Fleming for drawing my attention to the two 1949 records. Mr P. Smith of Newfoundland Broadcasting Company kindly lent film footage of the Bay Bulls specimen. I am indebted to Dr W. O. Pruitt, Jr., Memorial University Department of Biology, for the photograph accompanying this note (Fig. 1) and for discussions on this specimen.

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Received for publication August 25, 1967.

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A Portable Recompression Chamber for Treatment of Victims of Diving Accidents

In conjunction with the Royal Canadian Navy and Protective Plastics, Ltd., Toronto, the Biological Station of the Fisheries Research Board of Canada at Nanaimo, B.C., has been instrumental in developing a portable recompression chamber for on-site hyperbaric treatment of victims of diving accidents. It provides a pressurized vessel for their transportation to more extensive treatment facilities.

The chamber consists of a filament-wound fibreglass reinforced plastic shell $\frac{3}{16}$-inch thick and is 7 ft in length with an average diam of 2 ft (Fig. 1). The entrance hatch is of aluminum and completely removable. The anterior coaming is bounded by an adapter ring that enables the entire vessel to be attached to the medical lock of a treatment chamber allowing patient transfer under constant pressure.

The chamber has a maximum operational pressure of 75 p.s.i. and has been tested to 200 p.s.i. Fibreglass rather than metal permitted the construction of a relatively light vessel weighing 172 lb, easily transported by a small truck,

FIG. 1. Fibreglass portable recompression chamber.

J. FISH. RES. BD. CANADA, **24**(12), 1967.
Printed in Canada.

aircraft, or helicopter. Compact, portable consoles may be fabricated or purchased with the chamber, which is now being marketed commercially.

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Received for publication August 9, 1967.

Atlantic Salmon Caught in the Irminger Sea

Investigations to find one of the migration routes which Atlantic salmon follow on their way to or from Greenland, were carried out by the Danish research vessel *Dana* by drift-netting experiments in the Irminger Sea at the end of June 1966. Because of limited time, the fishery was carried out only during 5 nights successively on different stations every night. The route along the 62°00′N lat was chosen because the Irminger Current, a branch of the Gulf Stream and hence relatively warm, follows more or less this latitude.

The drift-nets used were 30 m long and 5 m deep. The mesh-sizes were 40, 60, and 70 mm, measured from knot to knot (equalling nearly 80, 120, and 140 mm respectively as stretched mesh).

Table I gives details of the fishing operation, and Table II reports the catches. The four salmon were all caught in nets with a mesh-size of 60 mm. Descriptions of them are given in Table III.

TABLE I. The details of fishery.

June 1966	Station	Position	Time, GMT		No. of nets			Surface temp (*C*)
			Setting	Hauling	40 mm	60 mm	70 mm	
24	13611	62°00′N;26°50′W	2115	0710	18	18	19	9.46
25	13612	62°00′N;30°20′W	2205	0550	12	22	22	8.69
26	13613	62°00′N;33°50′W	2345	0700	16	24	20	8.64
27	13614	62°00′N;37°20′W	2335	0735	19	22	19	8.24
28	13616	62°03′N;40°53′W	2300	0700		Total 60		7.41

TABLE II. The catches on the different stations.

Station	Catches	
13611	1	*Paralepis* sp.
13612	2	*Salmo salar*
	2	*Phocaena phocaena*
13613	1	*Cyclopterus lumpus*
13614	2	*Salmo salar*
13616	–	

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Printed in Canada.

TABLE III. The dates and measurements of the four *Salmo salar* from the Irminger Sea.

Station	Fork length (*cm*)	Weight (*kg*)	Condition factor[a]	Age	Sex	Stomach content
13612	52.0	1.35	0.96	1.1+	♀	*Themisto gaudichaudi*
"	52.5	1.45	1.00	1.1+	♂	" "
13614	60.0	2.10	0.97	2.1+	♂	11 *Brachioteuthis riisei*
"	55.0	1.65	0.99	3.1+	♀	27 " "
						And few *T. gaudichaudi*

[a]Condition factor $K = \frac{W \times 100}{L^3}$.

The length–weight relationship, as expressed by the condition factor, $K = 100 \times W/L^3$, was smaller for these four salmon than for salmon caught at West Greenland 2 months later at the end of August, 0.98 in contrast to 1.08. This increases in another 3 months to 1.40. The length of the specimens from the Irminger Sea (52.0–60.0 cm fork length) was smaller than usual in Greenland, where the mean fork length from 121 salmon measured in mid-August 1966 at Frederikshab was 62.2 cm.

The age in the sea, .1+, is the same as that of nearly all salmon caught at Greenland.

The investigation of the stomach content shows that the salmon caught in the Irminger Sea had eaten the hyperine amphipod, *Themisto gaudichaudi*, and the cephalopod, *Brachioteuthis riisei*. In contrast stomach contents from salmon caught at West Greenland show that the main food there is capelin and also sand-eel and euphasiids.

The Irminger Sea salmon may have been on their way to Greenland; the age, length, condition factor, time of the year, and locality of the catch fulfil the conditions for such a hypothesis.

The author is very much indebted to Mr W. Shearer, who has kindly read the scales.

Greenland Fisheries Investigations
Charlottenlund, Denmark

JENS MØLLER JENSEN

Received for publication August 9, 1967.

Erratum: Correct Spelling of *Alectridium aurantiacum*

In the recent paper on *Alectridium aurantiacum* by Peden (1967), an unfortunate error occurred. Gilbert and Burke (1912) described this North Pacific prickleback as *Alectridium aurantiacum*. This is the correct spelling and the unfortunate use of the spelling "*auranticum*" must be considered a *lapsus calami* as referred to by Article 32a (ii) of the International Commission on Zoological Nomenclature (1961).

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Received for publication July 5, 1967.

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J. FISH. RES. BD. CANADA, **24**(12), 1967.
Printed in Canada.

INDEX TO PUBLICATIONS FOR 1967[1]

In 1957 the Fisheries Research Board of Canada published Bulletin 110 containing a list of the articles in most of its series of publications and Studies that had appeared up to the end of 1954, together with a subject–author index to many of those series. That Bulletin is now out of print. A successor to it that will list and index all Board publications and Studies up to the end of 1964, plus many items that did not get included in the Studies, is completed and is expected early in 1968.

From 1955 to 1964 inclusive, a subject–author index to all articles in the Journal only has been included in the last issue of each Journal volume. Commencing with the 1965 volume of the Journal, the annual index was expanded to cover not only articles in the issues of that volume, but also such Fisheries Research Board of Canada Bulletins, Circulars, and Studies issued during the year in time to be included in the index.

Since 1966 the Journal has been issued monthly instead of bi-monthly. The present subject–author index is based on: (*a*) the 12 issues of Volume 24 of the Journal; (*b*) Bulletins 156–161 issued during 1967; second editions of Bulletins 137 and 148, and Bulletin 147 which was published in French. These titles are listed in the Lists of Publications for 1967 that follows this present index. (*c*) Circular series from the Board's establishments issued during 1967 in time to be included; (*d*) Studies No. 1110–1191 (reprints of articles published in other periodicals, bound annually in two parts); (*e*) general references to the 1965 and 1966 Annual Reports; (*f*) 75 Interpretive Articles which appeared in non-Board publications, but which did not get included in the bound Studies (item *d* above). The next issue of the biennial Review of the Fisheries Research Board of Canada, for the years 1965 and 1966, will appear in early 1968. The designation "(F)" in the index indicates the article referred to was published in French. Lists of titles of the individual publications and articles immediately follow this index, arranged under the following types of publications. (The list of articles in this Volume 24 of the Journal is in the form of a table of contents of its 12 issues, suitable for binding with this volume.)

Abbreviations used in the index for types of publications:

J — Journal of the Fisheries Research Board of Canada
B — Bulletin of the Fisheries Research Board of Canada
AR — Annual Report of the Fisheries Research Board of Canada
R — Review of the Fisheries Research Board of Canada (biennial)

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[1]Subject index prepared by Neal M. Carter.

J. Fish. Res. Bd. Canada, 24(12), 1967.
Printed in Canada.

Circulars of the Fisheries Research Board of Canada:

CAG — Arctic Biological Station, Ste. Anne de Bellevue, Quebec
CHN — Halifax Laboratory, Halifax, N.S.
CNG — Biological Station, Nanaimo, B.C. (General series)
CNS — Biological Station, Nanaimo, B.C. (Statistical series)
CSG — Biological Station, St. Andrews, N.B.
CVG — Vancouver Laboratory, Vancouver, B.C.

Articles by FRB Staff published in non-Board publications:

S — Studies of the Fisheries Research Board of Canada
A — Interpretive Articles of the Fisheries Research Board of Canada

Other abbreviations:

The Provinces and Territories of Canada are abbreviated to:

Alta. (Alberta)	N.W.T. (Northwest Territories)
B.C. (British Columbia)	Ont. (Ontario)
Man. (Manitoba)	P.E.I. (Prince Edward Island)
N.B. (New Brunswick)	Que. (Quebec)
Nfld. (Newfoundland)	Sask. (Saskatchewan)
N.S. (Nova Scotia)	Yuk. (Yukon)

Certain geographical areas (particularly oceans) have their major subdivision designated by N (north), S (south), E (east), W (west), NE (northeast), etc., also Atl. (Atlantic), Pac. (Pacific).

Certain international commissions are commonly referred to as:
ICNAF (International Commission for the Northwest Atlantic Fisheries)
INPFC (International North Pacific Fisheries Commission)

In the index references, "re" is frequently used to imply "in relation to," "in connection with," and similar meanings; "vs." to imply such meaning as "in contrast to," "as opposed to."

A

Abnormality
J 24(10): 2195 (yellow-skinned sockeye salmon)
S 1190 (hooves of Sable Is., N.S., horses)

Abundance (*see also* Stocks)
CNG 77 (herring spawn, B.C., 1966)
80 (B.C. herring: recent abundance changes; forecasts)
S 1185 (haddock in ICNAF Subarea 3)
A 22, 36, 59, 62 (B.C. herring and spawn)
37 (B.C. groundfish potential)

Acanthephyra curtirostris (a deepsea shrimp)
J 24(5): 1101 (fatty acids composition)

Acanthocephala (spiny-headed worms)
J 24(7): 1627 (*Echinorhynchus lateralis* causing Nfld. brook trout mortality)
(9): 1911 (descriptions; parasitic on Nfld. freshwater fishes)

Acclimation (*see also* Oxygen, dissolved; Salinity, reactions to; Temperature, reactions to)
J 24(6): 1403 (newly hatched lobster larvae to salinity)
(7): 1507 (Atlantic salmon and rainbow trout to temperature)
(8): 1823 (hypophysectomized American eels to freshwater)
(11): 2267 (hematological of thermal, in rainbow trout)

Achromobacter species
J 24(1): 9 (in fresh lake whitefish)
S 1152 (*A. cholinophagum* as substrate in betaine, dimethylglycine, and sarcosine oxidation)
1178 (*A. cholinophagum* utilization of choline or betaine in phospholipid synthesis)

Acids, amino (*see also* Protein; Proteolysis)
J 24(6): 1291 (of freshwater fishmeals)
(7): 1607 (of rainbow trout muscle myogen)
S 1110 (re photosynthesis in algae)
1119 (lobster hemolymph)
1152 (formaldehyde formation in oxidation of derivatives by marine bacterium)

Acids, fatty (*see also* Lipids; Oils and fats; Triglycerides)
J 24(2): 467 (of pink shrimp vs. a euphausid)
(3): 613 (seasonal composition changes in Atlantic cod liver, flesh, roe, and milt lipids)
(3): 635 (structure in marine animal lipids by GLC; particularly pristanic and phytanic acids)
(5): 1101 (composition of some marine animals from various depths off California)
(6): 1219 (of sheepshead, tullibee, burbot, and alewife oils)
(12): 2563 (of low iodine value from Greenland halibut, sablefish, and Atlantic herring)
S 1111 (fin whale oil re zooplankton feed of whale)
1118 (positional distribution in fats of polar bear and harbour seal blubbers)
1136 (storage of oxidizable esters in glass capillaries)
1151 (esterification of ozonides products)
1163 (calculating equivalent-chain-length values in GLC of multiple-branched)
1177 (quantitation problem in GLC of cod liver esters)
1184 (of coho salmon fingerlings fat)
1186 (of depot vs. dietary fats in Atlantic salmon, trout, and lobster)

Acids, nucleic (*see also* Nucleosides)
S 1112 (derivatives formed by salmon and trout testes)

Ackerman, Benjamin Franklin
J 24(12): 2637 (portable recompression chamber)

Ackman, Robert George
J 24(2): 357 (α-tocopherol in some Atl. fish and shellfish)
(2): 457 (blackberry in cod)
(2): 467 (fatty acid composition of the decapod shrimp)
(3): 613 (seasonal changes in cod fatty acid composition)
(3): 635 (marine fatty acids)
(6): 1219 (freshwater fish oils)
(7): 1521 (isopropyl alcohol in fish protein)
(12): 2563 (Canadian marine oils)
S 1110 (photosynthesis in green algae)
1111 (lipids of fin whale)
1136 (fatty acid methyl esters storage)
1151 (unsaturated fatty acids ozonolysis)
1159 (dimethyl-β-propiothetin)
1163 (fatty acids ECL values)
1175 (lipids and fish quality)
1177 (cod liver lipids fatty acid esters)
1183 (photosynthesis in algae)
1184 (coho salmon fingerling fatty acids)
1189 (freshwater fish oils)
A 40 (dimethyl-β-propiothetin)

Activity, coefficient of
S 1162 (of sodium sulphate in sea water)

Activity; Exercise; Fatigue (*see also* Stress)
J 24(5): 1117, (8): 1731 (swimming stamina of sockeye salmon fry)
(8): 1701 (disturbance of rainbow trout effects)

Adenosine derivatives
J 24(8): 1701 (phosphate in disturbed rainbow trout muscle)

(8): 1717 (monophosphate aminohydrolase of Atlantic cod prerigor and postrigor muscle)
A 30 (enzymic degradation in fish muscle)

Adrenaline and derivatives
J 24(8): 1701 (disturbance effects on concentration in rainbow trout)

Aëropsis fulva (*see* Sea urchins)

Agarum (*see* Kelps)

Age; Age-groups (*see also* Otoliths; Scales, fish)
J 24(5): 1035 (of blue pike in Lake Erie commercial fishery)
(5): 1077 (American plaice in Nfld. area)
(5): 1165 (re shell weight of several British Isles aquatic molluscs)
(6): 1209 (hypothetical, and growth of Nfld. bait squid)
(6): 1253 (of zebrafish re resistance to zinc sulphate)
(7): 1531 (vs. fecundity, Atlantic cod)
(12): 2573 (& growth of Atlantic cod in Ogac Lake, Baffin Is.)
B 157: 14 (lobsters)
161: 5, 24 (goldeye from scales; age re fish size)
CNG 80 (Pacific herring re abundance, stocks, & mortality)
CNS 25 (composition of B.C. sockeye salmon 1912–63 catches)
S 1158 (heterogeneity in Atlantic cod & haddock commercial landings)

Agris, Paul Francis
J 24(8): 1819 (lampricide and anoxia on lamprey)

Ahmed, Muzammil
J 24(10): 2155 (*Ostrea lurida* and *Crassostrea* chromosomes)

Alaska
J 24(1): 1 (redescription of North Pacific prickleback; correction on J 24(12): 2641)
(1): 209 (adipose fin pigmentation of juvenile chinook vs. coho salmon)
(3): 687 (pot for experimental shrimp fishing)
(4): 893 (*Triaenophorus crassus* in sockeye salmon smolts)
(7): 1475 (oceanography of larger SE inlets)
(9): 1861 (phytoplankton dynamics in arctic Imikpuk Lake)
(10): 2069, (12): 2613 (sockeye salmon fry & smolt migratory behaviour)
(11): 2207 (annual oceanographic changes, SE coast)
(12): 2627 (king crab breeding off Kodiak Is.)
B 156 (Dixon Entrance physical oceanography)

Albacore (Atlantic and Pacific) (*Thunnus alalunga*)
B 160 (brine-spray freezing at sea)
A 44 (description; catches; B.C. coast)
54(F) (description of Atlantic type; B.C. fishery)

Alberni Inlet, B.C.
J 24(10): 2137 (kraft mill effluent pollution distribution)

Alderdice, Donald Francis
J 24(5): 1173 (insecticide effect on coho)

Alectrias species
J 24(1): 1 (distinction from *Alectridium* species)

Alectridium aurantiacum (*see* Prickleback, North Pacific)

Alepisaurus borealis (*see* Lancetfish (Pacific))

Alewife (*Alosa pseudoharengus*)
J 24(6): 1219 (oil yield & composition on reduction)
(6): 1291 (composition & nutritive value of meal)
S 1128 (in a Lake Superior bay)
1189 (oil fatty acids composition)

Alexander, Gaylord Ray
J 24(7): 1425 (*Salvelinus fontinalis* numerical changes and population regulation)

Algae (*see* classifications; *also* Phytoplankton, sea lettuce; Seaweeds)
S 1110 (photosynthesis in various species)
1113 (antibacterial activity of various species extracts)
1155 (Coulter electronic counter for quantitative estimation of suspended)
1159, 1183 (photosynthetic thetin in various unicellular)
1171 (aldolase activity of unicellular)
A 40 (same as S 1159 above)

Algonquin Park, Ont.
J 24(5): 965 (pyloric caeca & gill raker development in lake trout)

Aliasing effect
J 24(8): 1827 (on long-term oceanic variability studies off Canada's coasts)

Alkalinity
J 24(5): 899 (of subarctic Pac. Ocean)

Allen, Ian V. Foster
J 24(2): 261 (marine-borer attack on wooden surfaces)

Allen, Kenneth Radway
J 24(12): 2595 (Atlantic salmon tagging and fin-clipping)
S 1126 (Greenland salmon fishery in Miramichi River, N.B.)

Allocentrus fragilis (*see* Sea urchins)

Alosa pseudoharengus (*see* Alewife)

Alsea River, Oregon
J 24(5): 917 (steelhead trout fecundity)

Ambloplites rupestris (*see* Bass, rock)

Amia calva (*see* Bowfin)

Ammocoete (*see* Lamprey)

Ammonia
J 24(6): 1419 (estimation method for freshwater fish excreta)

Ampelisca vadorum; *A. abdita* (*see* Amphipoda)

Amphigonopterus aurora (*see* Surfperches)

Amphipoda
J 24(1): 215 (*Eurythenes gryllus* preying on living longlined fish)
(2): 305 (*Ampelisca vadorum* & *A. abdita* biology)
(3): 687 (bioluminescence in 2 pelagic species)
S 1128 (in benthos of 4 Lake Superior bays)
A 14 (Great Bear Lake, N.W.T.)

Amphistichus argenteus (*see* Surfperch, barred)

Anabolism (*see also* Metabolism)
J 24(11): 2355 (re mathematical model for fish growth)

Analysis methods (*see also* Apparatus; Chromatography; Composition, chemical; Electrophoresis)
J 24(6): 1419 (ammonia in freshwater fish excreta)
(7): 1521 (isopropyl alcohol residues in protein concentrates)
(12): 2555 (phospholipase A assay)
S 1170 (alternative method for stereospecific, of triglycerides)

Anarhichas lupus (*see* Wolffish, Atlantic)

Anarhichas orientalis (*see* Wolffish, Bering)

Anatomy (*see also* Life history, etc.; *also* names of organisms)
J 24(2): 305 (*Ampelisca* amphipods sibling species pairs)
(2): 447 (trouts urinary & genital systems)
(3): 537 (review of fishes bioluminescent organs)
(9): 1911 (26 species of parasites from freshwater Salmonidae & Coregonidae)

Anchovy, northern (*Engraulis mordax mordax*)
J 24(5): 1101 (fatty acids composition)
A 70, 71(F) (brief description)

Andersen, Bruce Curon
J 24(9): 1999 (*Oncorhynchus nerka* gill rakers)

Anderson, John Murray
J 24(7): 1507 (*Salmo salar* and *S. gairdneri* temperature selection)
(7): 1515 (starvation on salmonid selected temperature)

Anderson, Robert Stewart
J 24(11): 2461 (plastic-bag water sampler)

Anesthesia
J 24(7): 1579 (techniques for Pac. salmon)

Anglerfishes (*see* Chaenophryne; Oneirodes)

Angling (*see also* names of sport fishes, e.g. Trout; Salmon)
B 158: 57 (re economics of N.W.T. commercial fisheries)
161: 37 (for goldeye)
A 14 (Great Bear Lake, N.W.T., grayling, yellow pickerel, etc.)
16 (summary of symposium on sport fishing economics)

Anguilla rostrata (*see* Eel, American)

Animal feed (*see* Feedstuff)

Anisakis (parasitic nematodes)
J 24(3): 629 (infestation as indicator of surf smelt populations heterogeneity)

Annelida
J 24(9): 1911 (parasitic on Nfld. trout)

Anodonta anatia (*see* Mussels, freshwater)

Anodonta californiensis (*see* Mussels, freshwater)

Anon.
S 1137 (1965 ICNAF research program)

Anoplarchus species
J 24(1): 1 (distinction from *Alectridium* species)

Anoxia
J 24(8): 1819 (re lampricide effectiveness on sea lamprey)
(10): 2169 (effect on rainbow trout blood serum proteins)

Antia, Navel Jamshedji
J 24(1): 201 (enzymes in algae)
S 1113 (marine planktonic algae antibacterial activity)
1145 (fucoxanthin optical activity)
1171 (unicellular red alga aldolase activity)

Antibiotics, tetracycline
J 24(4): 849 (for marking salmons)
(12): 2623 (effects in combating gaffkemia)

CNG 37 (for preserving herring on vessel prior to reduction)
A 12(F), 65 (as fillet preservative rendered ineffective by polyphosphate dips)
26 (review of use for fish & shellfish quality preservation)

Anticoagulant
J 24(7): 1579 (for salmonid blood during surgery)

Antigens; Antibodies
J 24(2): 443 (re serology of 2 Atl. oyster populations)

Antioxidants (*see also* Rancidity)
A 41 (review of research on)

Aplodinotus grunniens (*see* Sheepshead)

Apparatus
J 24(1): 9 (gamma irradiation of flesh)
(1): 77 (hatchery release tank for pink salmon fry)
(2): 357 (chromatographic eluent collection)
(2): 463 (gear for transporting *Mysis relicta* to lakes)
(3): 475 (determining oxygen influence on largemouth bass growth)
(3): 689 (shrimp pot for experimental fishing)
(4): 709, 731, 769, 823 (for determining effects of forest insecticide sprays on Atlantic salmon, trout, & aquatic insects)
(4): 883 (for sampling planktonic oyster larvae)
(5): 1033 (for measurement of small volumes)
(5): 1117 (flume for testing sockeye salmon fry swimming stamina)
(6): 1241 (for measuring maximum swimming speed of small fishes)
(7): 1461 (for freeze-drying Atlantic cod steaks)
(7): 1579 (for Pac. salmon anesthetic & surgical techniques)
(7): 1629 (for determining location of redds excavations by pink salmon)
(8): 1775 (chamber for cardiovascular dynamics of swimming adult sockeye salmon)
(8): 1811 (pumping system for sampling small marine plankton)
(10): 2137 (for pulp mill effluent concentration determination)
(11): 2309 (for Atlantic cod audiogram)
(11): 2321 (determining orientation of pink salmon fry early marine migration)
(11): 2461 (new plastic-bag water sampler)
(11): 2473 (simple lake model for instructional use)
(12): 2637 (decompression chamber for diving accidents)
B 159 (automatic underwater photography)
CNG 81 (hydraulic butter clam digger)
82 (otter trawl boards; bobbin groundline)
CVG 37 (preserving herring aboard vessel before reduction)
S 1134 (Atlantic oyster hatching)
1136 (capillary glass tubing for storing oxidizable fatty acid esters)
1154 (for sampling gases in bottom sediments)
1155 (Coulter electronic counter for aquatic particulate matter)
1157 (for measuring hydrogen sulphide oxidation kinetics)
1162 (for measuring activity coefficient of seawater sulphate)
1166 (for testing orientation of seaward-migrating young sockeye salmon)
1176 (3 types of scallop drags)
A 5(F) (for clamping lobster claws)
31 (quality tests with Telectron Fish Tester)
34 (pumps for unloading fish from vessels)
42 (for fish freezing by Mackenzie River delta Eskimos)
74 (same as CNG 82 above)

Arai, Hisao Philip
J 24(10): 2161 (parasite ecological specificity)

Arai, Mary Needler
S 1181 (Ceriantharian nervous system)

Arctic, Canadian (*see also* Oceanography, arctic)
J 24(3): 555 (Tanguary Fjord, Ellesmere Is., zooplankton)
(5): 975, 981 (Ogac Lake, Baffin Is., hydrography & biology)
(12): 2573 (Ogac Lake cod biology)
A 42 (fish freezer for Eskimos)
75 (Fisheries Research Board 1965 field activities)

Argentine, Atlantic (*Argentinia silus*)
A 43 (1965 Canadian ICNAF studies)

Argentinia silus (*see* Argentine, Atlantic)

Argyropelecus lychnus (*see* Lightfishes)

Artica islandica (*see* Quahaug, ocean)

Asteroidea (*see* Sea stars)

Atheresthes stomias (*see* Flounder, arrowtooth)

Atlantic Ocean (*see also* Hydrography; International Commission for the Northwest Atlantic Fisheries; Oceanography)
CAG 9 (populations of large whale species in western N)

Audiogram (*see* Sound, reactions to)

Avocettina bowersi (*see* Eels, snipe)

Axelson, Fritz
J 24(3): 683 (dolphin and tuna food)

B

Babine Lake and River system, B.C.
J 24(2): 299 (Catostomidae speciation in lake)
(2): 375 (sockeye salmon fry river ecology & behaviour)
(9): 1955 (mate selection in mixed age-groups sockeye salmon population)
(10): 2045, 2189 (primary production in lake system)

Bacillariophyceae (*see also* Diatoms)
S 1113 (extracts as bactericide)
1159 (photosynthetic thetin from several species)
A 40 (same as S 1159 above)

Bacteria
J 24(7): 1589 (role in *Gonyaulax* toxin production)
(12): 2623 (antibiotics & disinfectants for combating gaffkemia)
S 1113 (inhibition of various marine & terrestrial by marine algal extracts)
1140 (unidentified *Pseudomonas* causing rainbow trout skin lesions)
1152 (*Achromobacter cholinophagum* metabolism)
1161 (living carboniferous, in N.S. rock salt)
1165 (flora of stream-incubated pink salmon eggs)
1178 (choline utilization in phospholipid synthesis by *Achromobacter cholinophagum*)

Bactericides (*see also* Antibiotics; Disinfectants)
S 1113 (algal extracts)

Bacteria in fish processing and products (*see also* names of bacteria genera)
J 24(1): 9 (in fresh lake whitefish)
(2): 221 (in irradiated cooked lobster meat)
(5): 1179 (bacteriostatic effect of acetylated monoglycerides as dip for frozen Atlantic cod)
(8): 1827 (*Clostridium botulinum* spore germination in fish & shellfish extracts)

Baffin Island, Canadian Arctic (*see* Ogac Lake)

Bajacalifornia burragei (*see* Slickhead)

Balaenoptera borealis (*see* Whale, sei)

Balaenoptera musculus (*see* Whale, blue)

Balaenoptera physalus (*see* Whale, fin)

Balanus (*see* Barnacle)

Ball, Edward Arthur Robert
CNS 25 (B.C. sockeye catches, 1912–63)

Ball, Robert Cragin
J 24(3): 695 (low mobility proteins in fish blood)

Bams, Robert Abraham
J 24(5): 1117 (tests for differences in naturally and artificially propagated sockeye fry)

Bangiophyceae (*see Porphyridium*)

Bankia setacea (*see* Shipworms)

Barbados, West Indies
J 24(3): 683 (dolphin & yellowfin tuna feed)

Barker, Allan Mosley
J 24(6): 1413 (freeze-drying shellfish for solids)

Barnacle
J 24(1): 33 (*B. glandulus* vertical distribution, Indian Arm, B.C.)

Barr, Louis Marvin
J 24(3): 689 (experimental fishing shrimp pot)

Barraclough, William Edward
J 24(11): 2455 (Strait of Georgia herring)

Barracuda, ribbon (*Notolepis rissoi rissoi*)
J 24(10): 2101 (first record off B.C.)

Barrett, Burdette Eugene
J 24(5): 1177 (*Nealotus tripes* in Canadian Atl.)

Bartlett, Martin R.
J 24(9): 1991 (transatlantic tuna migrations)

Bass, largemouth (*Micropterus salmoides*)
J 24(3): 475 (oxygen concentration influence on juvenile growth)
(3): 695 (blood low-mobility proteins)
(6): 1241 (maximum swimming speed & conditioning to increased metabolism)

Bass, rock (*Ambloplites rupestris*)
J 24(3): 695 (blood low-mobility proteins)
(5): 927 (limnetic larvae in N Wisconsin lakes)
S 1128 (in 2 Lake Superior bays)

Bass, smallmouth (*Micropterus dolomieui*)
J 24(1): 87 (temperature re adult total annual growth)
(3): 695 (blood low-mobility proteins)
S 1128 (in 2 Lake Superior bays)

Bathylagus ochotensis (an argentinid fish)
J 24(10): 2101 (second record off B.C.)

Bathymetry (*see* Hydrography; Limnology; Oceanography)

Bathythermogram (*see also* Limnology; Oceanography)
J 24(5): 1155 (digitizing system for aperture cards)

Bayliff, William Henry
J 24(2): 249 (computer program for yield per recruitment)

Beamish, Frederick William Henry
A 61(F) (underwater camera)

Bear, polar (*Ursus arctos*)
S 1118 (fatty acids positional distribution in fat)

Beckett, James Stafford
J 24(5): 1177 (*Nealotus tripes* in Canadian Atl.)
(9): 1991 (transatlantic tuna migrations)

Beckford, Mascell Leonard
B 158 (fisheries of District of Mackenzie)

Beers, John Rudolph
J 24(8): 1811 (pumping system for plankton)
(10): 2053 (micro-zooplankton in euphotic zone across California Current)

Behaviour (*see also* Activity; Diel habits; Life history; Light, reactions to; Migration; Salinity, reactions to; Sound, reactions to; Swimming; Temperature, reactions to; etc.)
J 24(1): 77 (pink salmon fry in & after release from hatchery tank)
(2): 375 (& ecology, Babine R. sockeye salmon fry)
(3): 537 (re bioluminescence in fishes)
(6): 1403 (newly hatched lobster larvae to low salinity)
(8): 1743 (brook trout re artificial pond en route to sea)
(9): 1955 (sockeye salmon spawning & aggressive)
(10): 2069 (migratory,,of sockeye salmon fry & smolts)
(10): 2117 (Lake Huron white sucker population)
B 157: 15 (lobster)
S 1115 (killer whales unusual group)
1150 (Bay of Fundy herring re light)
A 61(F) (underwater photography for observing fish, re approach of fishing gear)
67 (bluefin tuna)

Bell, Gordon Russel
J 24(7): 1579 (Pac. salmon anesthetic and surgical techniques)
B 148 (general anaesthetics for fish)
S 1165 (salmon stream-incubated eggs microbial flora)

Bella Coola River system, B.C.
J 24(11): 2321 (orientation in early marine migration of pink salmon from)

Benthodesmus simonyi (*see* Frostfish)

Benthos
J 24(5): 1017 (profundal fauna of some Man. lakes)
(6): 1310 (of a guanotrophic small British lake)
S 1128 (of 4 Lake Superior bays)

Bering Sea
J 24(3): 581 (Ekman transport re zooplankton concentration)

Berkeley, Cyril
S 1138 (B.C. Polychaeta)

Berkeley, Edith and Cyril
S 1123 (list of polychaete type-specimens described by these authors, 1923–64)

Bernard, Frank Rheinhold
J 24(12): 2629 (new mollusc *Cuspidaria cowani*)
(12): 2637 (portable recompression chamber)

Berst, Alfred Hewitt
J 24(4): 887 (rainbow trout phenotypic characteristics)
(12): 2539 (lamprey parasitism of trout)

Betaine
S 1152 (oxidation by marine bacteria)
1178 (utilization in aerobic marine microbe phospholipid synthesis)

Bidgood, Bryant Frederick
J 24(4): 887 (rainbow trout phenotypic characteristics)

Biely, Jacob
J 24(6): 1291 (freshwater fish meals)

Bilinski, Edward
J 24(1): 201 (enzymes in algae)
(2): 273 (compounds in rainbow trout muscle)
(6): 1203 (binding of oil in canned salmon)
(12): 2555 (trout muscle phospholipase A activity)

Bilton, Hebert Thomas
CNS 25 (B.C. sockeye catches, 1912–63)

Bioluminescence
J 24(3): 537 (review of organs in fishes; significance of ventral)
(3): 687 (in two pelagic amphipod species)

Biomass
J 24(5): 1017 (profundal benthic fauna of some Man. lakes)

Birds
J 24(6): 1299 (causing guanotrophy of a small lake)
S 1132 (predatory on Atlantic salmon & trouts)

Bishop, Carol Marianne
J 24(11): 2339 (lobster muscle weight)
(12): 2549 (cod myotomal muscle)

Bivalves (*see also* Mollusca; *also* names of individual species, e.g., Clam; Mussel; Oyster; Scallop)
S 1169 (*Thracia conradi* common appearance, Malpeque Bay, P.E.I.)

Black, Edgar Clark
J 24(5): 939 (scale loss in rainbow trout)
(9): 1979 (obituary of)

Blackberry condition in Atlantic cod (*see* Thetin derivatives)

Blackwood (*see* Sablefish)

Bligh, Emerson Graham
J 24(6): 1219 (freshwater fish oils)
(6): 1291 (freshwater fish meals)

Blood; Blood plasma (*see also* Heart; Respiration; Serology)
J 24(1): 205 (mineralocorticoid activity, of skate)
(2): 429 (lethal endrin concentration, in gizzard shad)
(3): 695 (distribution of low-mobility proteins, in freshwater fishes)
(5): 939 (effect of partial descaling & desliming on rainbow trout)
(6): 1269 (protein electropherograms of lampreys)
(7): 1579 (anticoagulant for salmonid surgery)
(8): 1701 (rainbow trout disturbance effects on)
(8): 1775 (cardiovascular dynamics of swimming sockeye salmon adults)
(9): 1945 (hemoglobin protein electropherograms of *Sebastodes* species)
(10): 2169 (serum protein of rainbow trout after various stresses)
(11): 2267 (hematology of rainbow trout thermoacclimation)
(11): 2339 (hemocytes re serum proteins & muscle weight in lobsters)
S 1114, 1141, 1167, 1168 (hormones in skates plasma & tissues)
1116 (transcortin binding of cortisol in female Atlantic salmon plasma)
1119, 1144 (lobster hemolymph constituents)
1153 (plasma cortisol re Pac. salmon stresses)
A 11(F) (hormones isolated from skates plasma)

Blubber
J 24(3): 635 (fatty acids structure in oil from gray seal)
S 1111 (fatty acids in oil from fin whale)
1118 (fatty acids positional distribution in oil from polar bear & harbour seal)

Bluegill (*Lepomis macrochirus*) (bluegill sunfish)
J 24(3): 495 (reproductive isolation from pumpkinseed)
(3): 695 (blood low-mobility proteins)
(5): 927 (limnetic larvae in N Wisconsin lakes)

Bolton, Reginald Spence
J 24(7): 1613 (colour in grading canned salmon)

Bone (*see* Cranium; Jaw; Osteology; Vertebrae)

Boothby, Granville Forsyth
J 24(1): 211 (desiccation of frozen fish)

Borodulina infans (?) (*see* Eel, snipe)

Botulism
J 24(3): 595 (*Clostridium botulinum* spores rapid germination)
(4): 1833 (*C. botulinum* spore germination in fish & shellfish extracts)

Bouck, Gerald Ray
J 24(3): 695 (low-mobility proteins in fish blood)

Bourne, Neil
S 1176 (scallop drugs)
CNG 81 (new method of digging butter clams)

Bowfin (*Amia calva*)
J 24(3): 695 (blood low-mobility proteins)

Bowman, Thomas Elliot
J 24(3): 687 (amphipod bioluminescence)

Boyd, John William
J 24(1): 211 (desiccation of frozen fish)
(3): 527 (quality of dogfish during frozen storage)

Brachydanio rerio (*see* Zebrafish)

Brachyisteus aletes (*see* Surfperches)

Brachyisteus frenatus (*see* Perch, kelp)

Brama raii (*see* Pomfret)

Branchiura
J 24(9): 1911 (descriptions; parasitic on Nfld. trout & salmon)

Bras d'Or Lake, N.S.
J 24(2): 443 (serology of disease-susceptible oyster stock)

Brett, John Roland
J 24(8): 1731 (sockeye salmon fatigue)
(8): 1775 (sockeye cardiovascular dynamics)

Brines; Brining (*see also* Marinating; Salting)
J 24(8): 1693 (to produce light-salted Atlantic cod)
A 12(F), 65 (to lessen water loss during fillet processing)

Brinkhurst, Ralph Owen
J 24(6): 1299 (guanotrophy in Rostherne Mere)

Brill, Pacific (*see* Sole, petrale)

Brisaster latifrons (*see* Urchin, heart)

Brisaster townsendi (*see* Urchin, heart)

British Columbia (*see also* Oceanography, B.C. coast; *also* names of individual localities & bodies of water; *also* names of commercial fishery species)
J 24(6): 1421 (exotic earthworm species)
(6): 1203, (7): 1613 (grading canned salmon)

Brockerhoff, Hans
J 24(3): 607 (seasonal changes in cod condition and lipid content)
S 1118 (polar bear and seal fatty acids)
1125 (lobster triglyceride digestion)
1170 (triglyceride analysis)
1186 (dietary triglyceride conversion)

Brosme brosme (*see* Cusk)

Browning of flesh (Maillard browning)
S 1117, 1124 (role of sugars & sugar phosphates in postmortem fish)
A 30, 32 (enzymic removal of fish flesh carbohydrates to inhibit)

Bruce, David Lorne
S 1113 (marine planktonic algae antibacterial activity)

Brungs, William Aloysius
J 24(2): 429 (lethal endrin in blood of gizzard shad)

Bryozoa
J 24(9): 1905 (*Cribrilina annulata* sexual dwarfism)
(9): 2003 (*Figularia quaylei* new species from NE Pac.)

Budworm, spruce (*Choristoneura fumiferana*)
J 24(4): 701, 709, 731, 769, 807, 823 (re spraying of N.B. forests with insecticides to combat infestation; effects on salmon, trout, & aquatic insects)

Buerkle, Udo
J 24(11): 2309 (Atlantic cod audiogram)

Buffalo, smallmouth (*Ictiobus bubalus*)
J 24(2): 299 (muscle myogen electropherograms re speciation)

Bulkley, Ross Vivian
J 24(5): 917 (fecundity of steelhead trout)

Bullhead, black (*Ictalurus melas*)
J 24(3): 695 (blood low-mobility proteins)

Bullhead, brown (*Ictalurus nebulosus*)
J 24(3): 695 (blood low-mobility proteins)
S 1128 (in a Lake Superior bay)

Bullhead, yellow (*Ictalurus natalis*)
J 24(3): 695 (blood low-mobility proteins)

Burbot (*Lota lota*) (ling; maria)
J 24(5): 927 (limnetic larvae in N Wisconsin lakes)
(6): 1219 (oil yield & composition on reduction)
(6): 1291 (composition & nutritive value of meal)
(6): 1315 (cranial osteology)
S 1128 (in a Lake Superior bay)
1189 (oil fatty acids composition)
A 6(F) (marinated fillets & similar products)
14 (Great Bear Lake, N.W.T.)

Burgher, Robert Douglas
J 24(3): 607 (seasonal changes in cod condition and lipid content)

Bursa, Adam Stanislaw
S 1139 (*Discoasteromonas calciferus* n.sp.)
1191 (Great Bear Lake nannoplankton)
A 68 (scientific career)

Butler, David Gordon
J 24(8): 1823 (prolactin and eel electrolytes)

Butler, Terrance Henry
CNG 76 (Hectate Strait and Queen Charlotte Sound shrimp)

Buttkus, Hans
J 24(7): 1607 (amino acids in trout muscle myosin)

C

Caddisflies
J 24(4): 769, 807, 823 (affected by N.B. forest insecticide sprays, re their role as salmon & trout feed)
S 1128 (in benthos of 4 Lake Superior bays)

Caeca, pyloric
J 24(5): 965 (development in lake trout)

Cairns, Alan Andrew
J 24(3): 555 (zooplankton of Tanquary Fjord)

Calanus
J 24(3): 555 (*C. glacialis* & *C. hyperboreus* & *Pseudocalanus* in Tanquary Fjord, Ellesmere Is., zooplankton)

Calanus Expeditions
J 24(9): 1873 (decapod Crustacea collections, 1953, 1954, 1958–61)

California
J 24(5): 1101 (fatty acids composition of some marine animals)
(10): 2053 (Current: micro-zooplankton in euphotic zone)
(12): 2503 (description of stranded Cuvier's beaked whale)

Caligus (parasitic copepods)
S 1164 (nomenclatural confusion re *C. vicarius*)
1179 (synonomy of *C. japonicus* with *C. orientalis*)

Camera (*see* Photography)

Cancer magister (*see* Crab, Dungeness)

Canning; Canned products
J 24(6): 1203 (binding of oil in stored canned sockeye salmon)
(7): 1613 (standard colours for grading Pac. salmons)

Capelin (*Mallotus villosus*)
A 13(F) (description; value; distinction from similar fishes)

Carassius auratus (*see* Goldfish)

Carbohydrates (*see* Glucose; Glycogen; Sugars)

Carbon content (*see also* Productivity, primary)
J 24(5): 909 (in Saanich Inlet, B.C., particulate matter)

Cardiodectes medusaeus (parasitic copepod)
J 24(9): 1985 (on lanternfishes)

Cardium edule (*see* Cockle)

Carey, Andrew Galbraith, Jr.
J 24(6): 1385 (Echinodea of Oregon)

Caristius macropus (*see* Manefish)

Carotenoid pigments (*see also* Fucoxanthin; Xanthophylls)

Carp (*Cyprinus carpio*)
J 24(1): 47 (scale formation re growth in young)
(3): 695 (blood low-mobility proteins)
A 6(F) (marinated fillets & similar products)

Carpiodes cyprinus (*see* Quillback)

Carrothers, Percival John Godber
B 159 (underwater photographic equipment for fisheries research)

Castell, Charles Howell
J 24(2): 221 (radiation on storage of cooked lobster)
A 12(F) (fillet weight loss during storage)
28 (groundfish rancidity)
31 (Intelectron Fish Tester)
65 (fillet weight loss during storage)
73 (current technological research)

Castell, John Daniel
S 1151 (unsaturated fatty acids ozonolysis)

Catabolism (*see also* Metabolism)
J 24(11): 2355 (re mathematical model for fish growth)

Catches (*see also* Fisheries)
J 24(5): 1035 (Lake Erie commercial blue pike)
(6): 1187 (sampling of research trawl, at sea)
(12): 2527 (equilibrium, by rate of exploitation)
B 158 (of Mackenzie District, N.W.T., commercial freshwater fishes)
161: 33 (goldeye)
CNS 25 (age, size, & sex composition of B.C. sockeye salmon, 1912–63)
28 (1954–65 trawl production by Canadian & U.S. vessels off B.C.)
S 1137 (salmons in N Pac. Ocean by research longlining)
1148 (haddock, ICNAF areas by landings, 1921–62 re sea temperatures)
1158 (length & age compositions heterogeneity in Atlantic cod & haddock commercial landings)
1160 (trend-interpreting difficulties in Atlantic cod & haddock landings from E Scotian Shelf)
A 37 (B.C. & U.S. trawl-caught groundfish, 1956–63, off B.C.)
43 (commercial, in ICNAF Subareas 1–5, in 1965)

Catecholamine
J 24(8): 1701 (concentrations in disturbed rainbow trout)

Catfish, channel (*Ictalurus punctatus*)
J 24(3): 695 (blood low-mobility proteins)

Catostomidae
J 24(2): 299 (speciation by muscle myogen electropherograms)

Catostomus catostomus (*see* Sucker, longnose)

Catostomus commersoni (*see* Sucker, white)

Ceratium (dinoflagellates)
J 24(8): 1811 (recoveries by two plankton sampling methods)

Ceratophysa rosea (*see* Sea urchins)

Cercariae (flukes)
A 58 (parasitic larvae causing human "swimmers' itch" dermatitis)

Cerianthus
S 1181 (nervous system of *C. borealis*, *C. membranaceus*, & *C. solitarius*)

Cestoda
J 24(9): 1911 (descriptions, parasitic on Nfld. freshwater fishes)
(10): 2161 (*Eubothrium* parasitic on surfperches)

Chaenophryne parviconus (?) (an anglerfish)
J 24(10): 2101 (first record off B.C.)

Chaetoceros (*see* Diatoms; Phytoplankton)

Chalker, Dorothy Ann
J 24(1): 127 (thawing processes effects on cod and redfish)
A 27 (Nfld. trap cod)

Char (*see* Trout, lake)

Char, arctic (*Salvelinus alpinus*)
A 75 (possible yield in Keyhole Lake, Canadian Arctic)

Chicken
A 15 (nature of flesh flavours)

Chilling (*see also* Refrigeration)
B 160 (or partially freezing, salmon & tuna in refrigerated sea water)
A 26 (fish & shellfish with antibiotic ice)
41 ("superchilling")

Chironomidae (*see* Midges)

Chlorophyceae
S 1110, 1159, 1183 (photosynthesis products in several species)
1113 (extracts as bactericides)
A 40 (same as S 1159 above)

Choline and derivatives
J 24(2): 273 (in rainbow trout muscle stored at −4 C)
S 1178 (choline utilization in aerobic marine microbe phospholipid synthesis)

Choristoneura fumiferana (*see* Budworm, spruce)

Chorney, Victoria
S 1171 (unicellular red alga aldolase activity)

Chromatography
J 24(7): 1521 (GLC, for isopropyl alcohol residues assay in protein concentrates)
(8): 1701 (paper, for rainbow trout catecholamine)
(8): 1837 (thin-layer, for monitoring nucleotide degradation)
(10): 2195 (column, of sockeye salmon skin pigments)
(12): 2563 (GLC, for low-iodine-value fish fatty acids)
S 1121 (steroids destruction during silica-gel thin-layer)
1159 (thetins in algae)
1163 (calculating equivalent-chain-length values of GLC multiple-branched fatty acids)
1177 (quantitation problem in GLC of fatty acid esters)
A 40 (same as S 1159 above)

Chromosomes
J 24(10): 2155 (of Atl. & Pac. oyster)

Chrosomus eos (*see* Dace, northern redbelly)

Chrysophyceae
J 24(1): 201 (*Monochrysis lutheri* bacterial-toxin lecithinase C activity)
S 1113 (extracts as bactericides)
1159 (thetins from photosynthesis)
A 40 (same as S 1159 above)

Chub Lake, B.C.
J 24(10): 2189 (primary productivity)

Chubsucker, lake (*Erimyzon sucetta*)
J 24(3): 695 (blood low-mobility proteins)

Churchill, D. N.
J 24(3): 651 (postmortem changes in cod)

Ciliata
J 24(9): 1911 (parasitic on Nfld. brook trout)

Cisco (*see* Herring, lake; Tullibee)

Cisco, least (*Coregonus sardinella*)
A 14 (Great Bear Lake, N.W.T.)

Claggett, Freddie Gene
CVG 37 (summer herring preservation)

Clam (new species, *Cuspidaria cowani*)
J 24(12): 2629 (found off Queen Charlotte Is., B.C.)

Clam, Atlantic surf (*Spisula solidissima*)
J 24(6): 1413 (freeze-drying for total solids assay re condition)

Clam, butter (*Saxidomus giganteus*)
CNG 75 (prevalance & duration of toxicity, B.C. coast, & precautions for use)
81 (new digging method)
A 20 (description & biology, B.C.)

Clam, Japanese little-neck (*see* Clam, Manila)

Clam, little-neck (*Protothaca staminea*)
A 20 (description & biology, B.C.)

Clam, Manila (*Venerupis japonica* (Japanese little-neck clam)
A 20 (description & biology, B.C.)

Clam, razor (*Siliqua patula*)
A 20 (description & biology, B.C.)

Clam, soft-shell (*Mya arenaria*)
S 1182 (fishing efficiency of hacks & mortality)

Clark, Francis William
J 24(3): 495 (sunfish reproductive isolation)

Clarke, Livingston Wilberforce
J 24(2): 299 (Catostomidae electropherograms)

Cleaver, Frederick Charles
S 1129 (N Pac. Ocean salmon)

Clement, Philip Bruce
J 24(6): 1203 (binding of oil in canned salmon)

Cleugh, Thomas Reginald
S 1164 (*Caligus vicarius* Hewitt, 1963)

Clinocardium nuttali (*see* Cockle, basket)

Clostridium botulinum (*see* Botulism)

Clupea harengus (*see* Herring, Atlantic)

Clupea pallasii (*see* Herring, Pacific)

Coble, Daniel W.
J 24(1): 87 (temperature and growth in bass)
(10): 2117 (sea lamprey effects on South Bay white sucker population)

Coburn, Arthur Stephen
J 24(1): 77 (hatchery release tank for salmon fry)

Cocking, Anthony William
J 24(6): 1419 (indophenol method for freshwater fish ammonia estimation)

Cockle (*Cardium edule*)
J 24(5): 1165 (shell-weight re age, in Wales)

Cockle, basket (*Clinocardium nuttali*)
A 20 (B.C.)

Cod, Atlantic (*Gadus morhua*)
J 24(1): 127 (shelf life of water- vs. dielectric-thawed fillets)
(1): 145 (population dynamics of Arcto-Norwegian)
(2): 357 (α-tocopherol & lipids in tissues of unfed held)
(2): 457 (dimethyl sulphide & thetin re blackberry flesh condition)
(3): 607 (condition & lipid content seasonal changes in flesh & liver)
(3): 635 (structure details of liver oil)
(3): 651 (postmortem physicochemical changes in unfrozen)
(4): 895 (preservation of scrap as raw material for fish protein concentrate)
(5): 1179 (acetylated monoglycerides as bacteriostatic dip for frozen)
(6): 1315 (cranial osteology)
(7): 1461 (freeze-drying steaks)
(7): 1531 (fecundity in Nfld. & Labrador waters)
(8): 1693 (light-salted preparation by brining)
(8): 1717 (adenosine monophosphate aminohydrolase in prerigor and postrigor muscle)
(8): 1837 (nucleotide degradation re postmortem changes in relaxed muscle)
(11): 2309 (audiogram re cardiogram)
(11): 2398 (oxygen consumption mathematics)
(12): 2549 (white striated myotomal muscle ultrastructure)
(12): 2573 (biology in Ogac Lake, Baffin Is.)
S 1135 (metabolism of glyoxalate & pyruvate by sperm)
1158 (heterogeneity in length & age compositions of commercial landings)
1160 (trend-interpreting difficulties in landings from E Scotian Shelf)
1173, 1174 (pyruvate metabolism in testes; ovarian tissue)
1175 (review of lipids changes effects on quality of frozen)
1186 (biosynthesis of depot fat from dietary triglycerides)
1189 (liver oil fatty acids composition & structure)
A 12(F), 65 (fillet weight gains & losses when dipped in tap water or brines)
27 (environmental & physiological effects on quality of Nfld. trap-caught)
28 (metal-catalyzed rancidity in frozen)
30 (enzymic degradation of muscle glycogen & adenosine phosphate)
31 (quality assessment by Intelectron Fish Tester)
43 (1965 Canadian ICNAF research)

Cod, gray (*see* Cod, Pacific)

Cod, Greenland (*Gadus ogac*)
A 75 (population studies in central Canadian Arctic, 1965)

Cod, Pacific (*Gadus macrocephalus*) (gray cod; true cod)
J 24(3): 691 (shrinkage factor in measuring lengths)
CNG 78 (review of B.C. trawl fishery & 1967 forecast)
82 (1966 Hecate Strait exploratory fishing catches)
CNS 28 (Canadian & U.S. trawl catches off B.C., 1954–65)
A 2 (B.C. trawl fishery)
23 (description; biology; B.C.)

37 (B.C. & U.S. trawl catches off B.C., 1956–63, & fisheries potential)

Coleoptera
J 24(4): 823 (effect of phosphamidon insecticide on)

Cololabis saira (*see* Saury, Pacific)

Colour (*see also* Pigments)
J 24(7): 1613 (standard surfaces for grading canned Pac. salmon for colour, colour theory)

Commissions (*see* International)

Composition, chemical (for waters, *see* Limnology, Oceanography; *see also* Acids, amino; Acids, fatty; Oils; Protein)
J 24(4): 895 (protein concentrate from Atlantic cod scrap)
(6): 1291 (freshwater fishmeals)
(6): 1413 (freeze-drying shellfish for total solids assay)

Condition
J 24(3): 607 (seasonal changes in Atlantic cod flesh & livers)
(6): 1413 (freeze-drying oysters & clams for total solids assay)
A 66 (of lobsters)

Conservation (*see also* Management; Rehabilitation)
B 161: 39 (goldeye)

Constantinea subulifera
J 24(1): 33 (vertical distribution, Indian Arm, B.C.)

Continental Shelf
J 24(9): 1845 (bottom residual drift, Canadian Atl. coast)

Copepoda (*see also Calanus*; *Sphyrion*)
J 24(2): 231 (2 new species, Strait of Georgia, B.C.)
(3): 515 (*Phrixocephalus cincinnatus* morphology)
(9): 1911 (descriptions & one new species; parasitic on Nfld. freshwater fishes)
(9): 1985 (*Cardiodectes medusaeus* parasitic on lanternfishes)
(10): 2161 (3 species parasitic on surfperches)
S 1164 (nomenclatural confusion re *Caligus* species)
A 14 (Great Bear Lake, N.W.T.)

Copper compounds
J 24(10): 2169 (sulphate effect on rainbow trout blood serum proteins)
A 28, 73 (in catalyzing rancidity for experiments on fish quality changes)
58 (sulphate as molluscicide)

Cordova Bay, Victoria, B.C.
S 1120 (tracing currents by aerial photography, re coastal pollution)

Coregonus artedii (*see* Tullibee)

Coregonus clupeaformis (*see* Whitefish, lake)

Coregonus sardinella (*see* Cisco, least)

Cormier, Maurice George
J 24(2): 357 (α-tocopherol in some Atl. fish and shellfish)

Cornick, John Walter
J 24(11): 2339 (lobster muscle weight)
(12): 2623 (gaffkemia susceptibility)
S 1144 (lobster hemocytes)

Corn oil
S 1170 (stereospecific analysis of triglycerides)

Corticosterone derivatives (*see* Hormones)

Cortisol (*see also* Hormones)
S 1116 (transcortin binding in Atlantic salmon plasma)
1153 (of sockeye salmon plasma re stress)

Corynebacterium species
J 24(1): 9 (in fresh lake whitefish)

Coryphaena hippurus (*see* Dolphin (Atlantic))

Coryphaenoides acrolepis (*see* Rat-tail, roughscale)

Coryphopterus nicholsi (*see* Goby, bluespot)

Costaria costata
J 24(1): 33 (vertical distribution, Indian Arm, B.C.)

Cottus bairdi (*see* Sculpin, mottled)

Cottus cognatus (*see* Sculpin, slimy)

Crab, Dungeness (*Cancer magister*)
J 24(8): 1833 (botulinum spore germination in tissue extracts)

Crab, king (*Paralithodes camtschatica*)
J 24(12): 2627 (breeding in ocean environment)

Craigie, J. S.
S 1110 (photosynthesis in green algae)
1183 (photosynthesis in algae)

Craneflies
J 24(4): 769 (as affected by N.B. forest insecticide sprays, re their role as salmon & trout feed)

Cranium
J 24(6): 1315 (osteology of Gadidae)

(7): 1623 (California sea lion found off Nfld.)
(12): 2503 (stranded Cuvier's beaked whale)

Crappie, black (*Pomoxis nigromaculatus*)
J 24(3): 695 (blood low-mobility proteins)
(5): 927 (limnetic larvae in N Wisconsin lakes)

Crassostrea gigas (*see* Oyster, Pacific)

Crassostrea virginica (*see* Oyster, Atlantic)

Crayfish
S 1128 (sex ratio of Lake Superior *Orconectes*)

Crean, Patrick Bernard
B 156 (physical oceanography of Dixon Entrance, B.C.)

Crecy Lake, N.B.
S 1132 (bird predation on salmon & trouts)
1133 (movement of planted hatchery-reared trouts from)

Crepidula formicata (a colonial gastropod)
J 24(5): 1165 (shell-weight re age in British waters)

Cribrilina annulata (a bryozoan)
J 24(9): 1905 (sexual dwarfism)

Crinoids
J 24(4): 833 (2 species from a drifting ice island off E Greenland)

Cristivomer namaycush (*see* Trout, lake)

Crouch, River (England)
J 24(3): 569 (feeding & migration of pink shrimp)

Crustacea (*see also* Amphipoda; Crab; Gribble; Lobster; Prawn; Shrimp)
J 24(5): 1101 (fatty acids composition of various)
(9): 1873 (list of decapods collected in Hudson Bay)

Cryptophyceae
S 1113 (extracts as bactericides)
1159 (photosynthetic thetin in)
A 40 (same as S 1159 above)

Currents (*see also* Oceanography; Tide)
J 24(10): 2053 (micro-zooplankton in California Current euphotic zone)
B 156: 33, 59 (Dixon Entrance & Hecate Strait, B.C.)
S 1120 (traced by aerial photography re coastal pollution)

Cusk (*Brosme brosme*)
A 43 (1965 Canadian ICNAF studies)

Cusk-eel, fawn (*Lepophidium cervinum*)
J 24(1): 213 (range extension N to southern N.S.)

Cuspidaria cowani
J 24(12): 2629 (new clam species, B.C.)

Cymatogaster aggregata (*see* Perch, shiner)

Cyphocaris challengeri (a pelagic amphipod)
J 24(3): 687 (bioluminescence)

Cyprinus carpio (*see* Carp)

Cytology (*see also* Histology)
J 24(10): 2155 (chromosomes of Atl. & Pac. oyster)
S 1139 (*Discoasteromonas calciferus*, new relict flagellate)

D

Dace, blacknose (*Rhinichthys atratulus*)
S 1132 (predation by birds, Crecy Lake, N.B.)

Dace, longnose (*Rhinichthys cataractae*)
S 1128 (in 3 Lake Superior bays)

Dace, northern redbelly (*Chrosomus eos*)
S 1132 (predation by birds, Crecy Lake, N.B.)

Dafoe, Thomas
S 1162 (sodium sulfate in sea water)

Dahlberg, Michael Lee
J 24(1): 209 (fin pigmentation to distinguish Alaska chinook and coho)

Dambergs, Nikolajs
J 24(4): 895 (isopropyl alcohol preservation of fish protein concentrate raw material)

Darter, Iowa (*Etheostoma exile*)
S 1128 (in 2 Lake Superior bays)

Darter, Johnny (*Etheostoma nigrum*)
S 1128 (in 4 Lake Superior bays)

Darters (*Etheostoma* species)
J 24(5): 927 (limnetic larvae in N Wisconsin lakes)

Davis, John Christopher
J 24(8): 1775 (sockeye cardiovascular dynamics)

DDT (*see* Insecticides)

Decapoda (*see also* subclassifications)
J 24(5): 1101 (fatty acids composition of *Acanthephyra curtirostris*, *Pasiphaea* sp., *Pleuroncodes planipes*)
(9): 1873 (list of, collected in Hudson Bay)

(11): 2467 (measuring feed retained by *Palaemonetes pugio*)
S 1128 (in benthos of 4 Lake Superior bays)

DeLacy, Allan Clark
J 24(3): 629 (parasites among surf smelts)

Delphinapterus leucas (*see* Whale, white)

Denaturation (*see* Protein)

Dendraster excentricus (*see* Sea urchins)

Density of natural waters (*see* Hydrography; Limnology; Oceanography)

Depth (*see also* Hydrography; Limnology; Oceanography)
J 24(11): 2491 (computer vs. manual calculations)

Dermatitis, schistosome
A 58 (cause, control, & treatment of "swimmers' itch" on humans)

Dermocystidium (fungus)
J 24(4): 843 (on prespawning adult chinook salmon)

Desiccation (*see also* Freeze-drying)
J 24(1): 211 (of stored cartoned frozen sole fillets)

Detritus (*see* Matter, particulate; Sediments)

Development (*see also* Growth; Life History)
J 24(1): 47 (young carp)
(5): 955 (purines in Atlantic salmon integument during parr–smolt transformation)
(5): 965 (pyloric caeca & gill rakers in lake trout)
(12): 2573 (of Atlantic cod in Ogac Lake, Baffin Is.)

DeWilde, Mary Anne
J 24(11): 2267 (trout hematology)

Diaphus theta (*see* Lanternfish, theta)

Diatoms (*see also* Bacillariophyceae)
J 24(5): 909 (in Saanich Inlet, B.C., particulate matter)
(8): 1811 (recoveries by two plankton sampling methods)
S 1172 (size, re availability as zooplankton feed)

Dickie, Lloyd Merlin
S 1158 (groundfish heterogeneity)
1160 (Scotian Shelf cod and haddock trends)

Diel habits (see also Behaviour; Light, reactions to; Salinity, reactions to; Temperature, reactions to)
J 24(2): 375 (Babine R. sockeye salmon fry)
(10): 2069 (sockeye salmon fry & smolts migratory behaviour)
(12): 2515 (starry flounder & sand sole feeding)
S 1166 (re orientation of seaward-migrating sockeye salmon)

Digenea
J 24(10): 2161 (*Telolecithus* & *Neozoogonus* parasitic on surfperches)

Digging
CNG 81 (new hydraulic method for butter clams)
S 1182 (efficiency of forking soft-shell clams; mortalities)
A 58 (human dermatitis from clam digging)

Dilution effect (*see also* Estuary; Oceanography)
J 24(11): 2283 (of rainfall on phytoplankton productivity in a lake)
B 156: 9, 47 (of rivers runoff, on Dixon Entrance, B.C., oceanography)

Dingle, John Reginald
J 24(4): 873 (scallop muscle protein)
(8): 1717 (cod muscle enzyme)
(8): 1837 (postmortem cod muscle)
S 1119 (*Homarus americanus* hemolymph constituents)
1144 (lobster hemocytes)

Dinoflagellata (*see Ceratium*; *Gonyaulax*; *Gymnaster*; *Noctiluca*; *Tetraselmis*)

Dinophyceae
S 1113 (extracts as bactericides)
1159 (photosynthetic thetin in)
A 40 (same as S 1159 above)

Dips for preserving fish quality
A 12(F), 65 (for retarding water losses in fillets)
26 (antibiotic)

Diptera (Tipulidae; Empidae) (*see also* Flies, black)
J 24(4): 769, 823 (affected by N.B. forest insecticide sprays, re their role as salmon & trout feed)

Discoasteromonas calciferus
S 1139 (new arctic relict flagellate species)

Discoloration (*see also* Browning of flesh; Pigments)
B 160 (reddening of salmon flesh held in refrigerated sea water)
CHN 30 (gill-netted Greenland halibut flesh)
S 1180 (removal of fish tank brown stain by sulphur dioxide)

Disease; Pathology (*see also* Histology; Parasites)

J 24(2): 443 (serology of 2 Atl. oyster populations)
(3): 679 (tumor-like growth on freshwater mussel foot)
(4): 843 (fungus on chinook salmon)
(4): 867 (histopathology of "gas bubble" disease in salmon)
(9): 2007 (neurofibroma in snake prickleback)
(12): 2623 (disinfectants & antibiotics effects on *Gaffkya* re lobster disease)
S 1140 (bacterial skin lesions on rainbow trout)

Disinfectants; Disinfection (*see also* Bactericides)
J 24(12): 2623 (for combating gaffkemia)
B 160 (for holds or tanks for chilling or freezing fish aboard vessels)

Distephanus speculum (a silicoflagellate)
S 1191 (in Great Bear Lake, N.W.T.)

Distribution (biological) (*see also* Marking; Migration; Tagging)
J 24(1): 33 (vertical, of benthic marine algae, Indian Arm, B.C.)
(2): 451 (of E Pac. harbour seals re pelage patterns)
(6): 1385 (vertical, of Oregon echinoids)
(7): 1629 (randomness in pink salmon redds)
B 157: 14 (lobster)
161: 3 (goldeye)
S 1137 (salmons in N Pac. Ocean)
1147 (haddock re season, depth, & bottom temperature)
1188 (harbour seal in Canadian Arctic)
A 36 (B.C. herring populations)
43 (swordfish catches off Canadian Atl. coast, 1965)
67 (bluefin tuna)

Diving, undersea
J 24(12): 2637 (decompression chamber for accidents)

Dixon Entrance, B.C.
B 156 (physical oceanography)
A 74 (good groundfish area found during exploration)

Dodimead, Allan John
J 24(11): 2207 (E subarctic Pac. waters changes)

Dogfish, Pacific (*Squalus suckleyi*)
J 24(3): 527 (quality during frozen storage)
CNG 79, 82 (catches, B.C., 1945–65)
80 (predation on herring)
CNS 28 (Canadian & U.S. trawl catches off B.C., 1954–65)
A 37 (B.C. & U.S. landings, 1956–63, & fisheries potential)

Dogfish, spiny (*Squalus acanthias*)
J 24(2): 357 (α-tocopherol & lipids in tissues of unfed held)

Dogwinkle, Atlantic (*Thais lapillus*)
J 24(2): 357 (α-tocopherol & lipids in unfed held)

Dolphin (Atlantic) (*Coryphaena hippurus*)
J 24(3): 683 (feed of, in Barbados waters)

Dolphin, euphrosyne (*Stenella euphrosyne*)
S 1190 (stranded on Sable Is., N.S.)

Dombrowski, Heinz
S 1161 (rock salt bacteriological investigation)

Donaldson, Edward Mossop
S 1187 (rainbow trout hypophysectomy effects)

Dorosoma cepedianum (*see* Shad, gizzard)

Doudoroff, Peter
J 24(3): 475 (oxygen on largemouth bass growth)

Dragonflies
J 24(4): 823 (effect of phosphamidon insecticide on)
S 1128 (in benthos of 4 Lake Superior bays)

Drags
S 1176 (efficiency & selectivity of 3 types for scallops)

Drift
J 24(9): 1845 (bottom residual, on Canadian Atl. coast Continental Shelf area)

Drinnan, Roy Ellis
S 1134 (Canadian oyster hatchery development)
CSG 51 (Canadian oyster hatchery development)
A 35 (rehabilitating oyster stocks)

Drip
J 24(3): 651 (re postmortem physicochemical changes in unfrozen Atlantic cod)
A 12(F), 65 (in Atlantic cod & flounder fillets)
27 (in thawed trap-caught Nfld. cod frozen at sea)

Drucker, Benson
J 24(10): 2069 (sockeye migratory behaviour)

Druehl, Louis Dix
J 24(1): 33 (distribution of algae)

Drum (*see* Sheepshead)

Duff, David Cecil Buchanan
S 1113 (marine planktonic algae antibacterial activity)

Dugal, Louis Charles
J 24(11): 2229 (iced freshwater fish hypoxanthine)
S 1180 (fish tank stain removal)

Dugesia dortocephala (*see* Flatworm)

Dunaliella (an alga)
S 1110, 1159 (photosynthesis in)
1113 (extract as bactericide)

Dussault, Henri Paul
J 24(5): 1179 (acetylated monoglycerides as frozen fish coating)

Dwarfism
J 24(9): 1905 (sexual, in bryozoa *Cribrilina annulata*)

Dyeing
B 161: 36 (during goldeye processing)
S 1120 (sea water for tracing currents by aerial photography)

Dyer, William John
J 24(1): 127 (thawing processes effects on cod and redfish)
(2): 221 (radiation on storage of cooked lobster)
(4): 873 (scallop muscle protein)
(8): 1837 (postmortem cod muscle)
A 69 (frozen fish muscle)

E

Eales, John Geoffrey
J 24(5): 955 (purines in parr–smolt Atlantic salmon)

Ear (*see* Sound, reactions to)

Earthworms
J 24(6): 1421 (exotic species in B.C. eaten by coho salmon)

Eaton, Catherine Anne
J 24(2): 467 (fatty acid composition of the decapod shrimp)
(6): 1219 (freshwater fish oils)
(12): 2563 (Canadian marine oils)
S 1111 (lipids of fin whale)

Echinoderms (*see also* subclassifications)
J 24(4): 833 (from a drifting ice island off E Greenland)

Echinoids (*see* Sea urchins; Urchin, heart)

Echinorhynchus lateralis (parasitic acanthocephalan)
J 24(7): 1627 (causing Nfld. brook trout mortality)

Echo sounding
A 36 (for B.C. herring)

Ecology
J 24(2): 375 (& behaviour, Babine R. sockeye salmon fry)
(10): 2117 (Lake Huron white sucker population)
(10): 2161 (re host specificity of fish parasites)

Economics
B 157 (appraisal of Canadian lobster industry)
158 (re District of Mackenzie, N.W.T., fisheries organization)
A 33 (lobster)
37 (re B.C. groundfish potentials)

Edwards, H.E.
J 24(4): 709 (fish losses after insecticide sprayings)

Eel, American (*Anguilla rostrata*) (yellow eel)
J 24(8): 1823 (ovine prolactin effect on hypophysectomized yellow)

Eel, yellow (*see* Eel, American)

Eelgrass (*Zostera marina*)
S 1122 (experimental chemical control in oyster areas)

Eelpout (*Zoarces viviparus*)
J 24(11): 2452 (gill surface index)

Eels, snipe
J 24(5): 1101 (*Serrivomer sector* & *Avocettina bowersi* fatty acids composition)
(10): 2101 (first records off B.C. of *Serrivomer jesperseni* & *Borodulina infans* (?))

Efficiency of fishery gear (*see* Apparatus; Effort; Gear; Selectivity of fishing gear)

Effluent (*see* Dilution effect; Pollution)

Efford, Ian Ecott
J 24(11): 2283 (Marion Lake, B.C., phytoplankton)

Effort and intensity of fishing
J 24(1): 145 (re total mortality, Arcto-Norwegian cod)
B 157 (re Canadian lobster fishery economics)
CNS 28 (Canadian & U.S. trawl catches off B.C., 1954–65)
S 1176 (efficiency of 3 types of scallop drags)
1182 (efficiency of hacks for digging soft-shell clams)

Eggs, fish (*see also* Fecundity)
J 24(1): 207 (wolffish, off N.S.)
(2): 375 (yolk absorption in sockeye salmon fry)
(3): 613 (seasonal lipids fatty acids changes in Atlantic cod)

(5): 917 (size, etc., re steelhead trout fecundity)
(7): 1573 (fertility duration, of pink & sockeye salmon)
B 161: 26 (goldeye)
CNG 77, 83 (herring, abundance & mortality, B.C., 1966; 1967)
S 1165 (microbial flora of stream-incubated pink salmon)
A 36 (mortality of Pacific herring)
59, 62 (lowest recorded abundance of herring spawn in B.C., 1966)

Electrocardiogram (*see* Heart)

Electronarcosis
J 24(1): 191 (factors for trout response in fresh & salt water)

Electrophoresis; Electropherograms
J 24(2): 299 (Catostomidae speciation re muscle myogens)
(3): 695 (of low-mobility proteins in freshwater fishes)
(4): 873 (of scallop striated muscle extracts)
(6): 1269 (of lamprey ammocoetes muscle myogen & blood protein)
(8): 1637 (of muscle protein from allopatric marine & freshwater stickleback & their hybrid)
(9): 1945 (of *Sebastodes* species, re new species *Sebastodes reedi*)
(10): 2169 (rainbow trout blood serum proteins)
S 1119 (lobster hemolymph)
1146 (insect oxidase–peroxidase system)

Ellerslie, P.E.I.
S 1134 (oyster hatching procedure developments)

Ellerslie Brook, P.E.I.
J 24(8): 1743 (brook trout movements re artificial pond en route to sea)

Ellis, Douglas Graham
J 24(4): 873 (scallop muscle protein)

Elson, Paul Frederick
J 24(4): 731 (DDT effects on wild young salmon)
A 25 (Atlantic salmon near Greenland)

Embiotoca jacksoni (*see* Perch, black)

Embiotoca lateralis (*see* Seaperch, striped)

Embryology (*see* Eggs, fish; Larvae)

Endrin
J 24(2): 439 (lethal level in gizzard shad blood)

England, Lucas Allison
A 35 (rehabilitating oyster stocks)

Engraulis mordax mordax (*see* Anchovy, northern)

Enteromorpha species
J 24(1): 33 (vertical distribution, Indian Arm, B.C.)

Entosphenus
J 24(5): 1067 (in lampreys key)

Enzymes
J 24(1): 201 (bacterial-toxin lecithinase C in marine algae & spinach)
(8): 1717 (Atlantic cod adenosine monophosphate aminohydrolase)
(12): 2555 (rainbow trout muscle phospholipase A activity & assay method)
S 1125 (lobster digestive lipase)
1140 (proteolytic bacterial, causing skin lesions)
1146 (oxidase–peroxidase system in insects)
1171 (aldolase activity in a unicellular red alga)
A 30, 32 (enzymic removal of fish flesh carbohydrates to inhibit browning)

Eopsetta jordani (*see* Sole, petrale)

Ephemeroptera (*see* Mayflies)

Eptatretus deani (*see* Hagfish, black)

Equipment (*see* Apparatus)

Equus caballus (*see* Horse, domestic)

Erie, Lake
J 24(4): 887 (rainbow trout phenotypic characteristics)
(5): 1035 (contributions of blue pike year-classes to commercial fishery)
A 39 (life history & fishery, American smelt)

Erilepis zonifer (*see* Skilfish)

Erimyzon sucetta (*see* Chubsucker, lake)

Eskimos
A 42 (fish freezing equipment for Mackenzie River delta)

Esox americanus vermiculatus (*see* Pickerel, grass)

Esox lucius (*see* Pike, northern)

Estuary
J 24(7): 1553 (hydrography, Penobscot R., Maine)
S 1120 (aerial photography of currents, Fraser R.)
A 52 (definition & oceanography of, in general)

Etheostoma exile (*see* Darter, Iowa)

Etheostoma nigrum (*see* Darter, Johnny)

Etheostoma species (*see* Darters)

Eubalaena glacialis (*see* Whale, right)

Eucalia inconstans (*see* Stickleback, brook)

Eulachon (*Thaleichthys pacificus*)
A 70 (brief description)

Euphausids
J 24(2): 467 (*Meganyctiphanes norvegica* fatty acids)
(6): 1229 (*Euphausia, Thysanoëssa,* & *Tessarabrachion* moulting & respiration)
S 1111 (*Meganyctiphanes norvegica* fatty acids re effect on whale oil)

Eurythenes gryllus (an amphipod)
J 24(1): 215 (predation on living longlined fish)

Evelyn, Trevor Patrick Todd
J 24(10): 2195 (sockeye salmon pigments)

Excreta
J 24(6): 1419 (estimating ammonia of, in freshwater fish)

Exercise (*see* Activity; Stress)

Exotics (*see* Species, new records or range extensions)

Exploitation
J 24(1): 145 (Arcto-Norwegian cod populations)
(10): 2117 (of a Lake Huron white sucker population)
(12): 2527 (mathematical treatment of, re multiple stocks)
B 157: 7, 14 (re Canadian lobster fishery economics)
CNG 78 (B.C. Pacific cod)
S 1126 (Greenland vs. Canadian Atlantic salmon fisheries)
A 17 (N American fishery potential)
18 (re unexploited stocks & fishery techniques)

Exploration; Prospecting
CNG 76 (for shrimps off Queen Charlotte Is., B.C.)
82 (for groundfish in Hecate Strait, B.C., 1966)
A 18 (re unexploited fishery stocks)
37 (re unexploited groundfish off B.C.)
74 (summary of CNG 82 above)

Export (*see also* Economics)
A 4(F) (Canadian live lobsters)

Eye (*see* Light, reactions to)

F

Faber, Daniel James
J 24(5): 927 (N Wisconsin limnetic larval fish)

Fagerlund, Ulf Henrik Mathias
S 1153 (sockeye plasma cortisol concentration)

Farley, John
A 58 ("swimmer's itch")

Fat (*see* Acids, fatty; Condition; Oils; Lipids; Phospholipids; Triglycerides)

Fatigue (*see* Activity; Stress)

Fatty acids (*see* Acids, fatty)

Fauna
J 24(5): 1017 (profundic benthic, of some Man. lakes)

Fecundity
J 24(5): 917 (steelhead trout in an Oregon river)
(7): 1425 (brook trout)
(7): 1531 (Atlantic cod in Nfld. & Labrador waters)
(8): 1637 (threespine stickleback hybrid)
(11): 2485 (re lingcod length–weight ratio)
CNG 77, 83 (Pacific herring)
A 5(F) (lobster)

Feed; Feeding habits; Stomach contents
J 24(1): 53 (of Atlantic halibut at maturity stages & spawning)
(2): 375 (of Babine R. sockeye salmon fry)
(2): 463 (*Mysis relicta* introduced into lakes for trout)
(3): 475 (re oxygen concentration & growth of largemouth bass)
(3): 569 (of English pink shrimp)
(3): 683 (West Indies dolphin & yellowfin tuna)
(4): 701, 769, 807, 823 (effect of insecticides on aquatic insects as feed of Atlantic salmon & trout)
(11): 2363 (re mathematical model for fish growth)
(11): 2467 (measuring retention of, by aquatic invertebrates)
(12): 2573 (Atlantic cod in Ogac Lake, Baffin Is.)
(12): 2515 (Puget Sound starry flounders & sand sole)
B 161: 26 (of goldeye)
S 1130 (squid habits)
1172 (zooplankton, re size of phytoplankton feed)
A 5(F), 66 (of lobsters)

Feedstuff (*see also* Fishmeal)
J 24(6): 1219, 1291 (freshwater fishes oils & meals)
CNG 79 (NE Pac. groundfish catches used for, 1954–65)
A 37 (NE Pac. groundfish catches used for, 1956–63, & fisheries potential)

Ferguson, Robert Gilmour
A 39 (American smelt)

Fertility
J 24(7): 1573 (duration of pink & sockeye salmon ova & sperm)

Figularia quaylei
J 24(9): 2003 (new bryozoan species, NE Pac.)

Fillets
J 24(1): 127 (water- vs. dielectric-thawing effect on shelf life of cod & redfish)
(1): 211 (desiccation of frozen cartoned, from sole)
(8): 1833 (botulinum spore germination in extracts from)
(11): 2229 (hypoxanthine formation in iced freshwater fish)
CHN 30 (discolored, from small gill-netted Greenland halibut)
A 6(F) (marinated, from freshwater fishes)
12(F), 65 (weight gains & losses of Atlantic cod, when dipped in tap water or brines)
A 26 (antibiotic dips for preserving quality)

Fingerlings (*see* names of adult fishes, e.g. Trout, Salmon)

Fins
J 24(1): 209 (adipose pigmentation for distinguishing juvenile chinook from coho salmon)

Fjords (*see* Inlets)

Fisheries (*see also* Catches; *also* names of commercial fishes, shellfishes, etc.)
J 24(5): 1035 (contributions of blue pike year-classes to Lake Erie commercial)
(12): 2527 (mathematical treatment of multiple stocks exploitation)
B 157 (economic appraisal of Canada lobster)
158 (physical & economic organization, Mackenzie District, N.W.T.)
161: 33, 37, 39 (commercial; sport; management; of goldeye)
CNG 78 (review of B.C. Pacific cod & 1967 forecast)
79 (recent developments in NE Pac. groundfish)
80 (recent abundance changes & future prospects, B.C. herring)
S 1126 (Greenland salmon, effect on N.B. salmon stocks & fishery)
1147, 1185 (haddock, ICNAF areas)
1148 (Atlantic cod, ICNAF areas)
1149 (Magdalen Is. herring)
A 2 (trawl for Pacific cod)
5(F) (Canadian & U.S. lobster)
8(F) (Atlantic herring in Canada)
9(F) (Atlantic mackerel in Canada)
10(F), 64 (giant scallop in Canada)
14(F) (Great Bear Lake, N.W.T.)
17, 53 (N American fishery potential)
18 (challenge of unexploited stocks & fishing methods)
20 (B.C. clams)
44, 54(F) (albacore, B.C.)
60 (same as CNG 79 above)
67 (bluefin tuna)

Fisheries Research Board of Canada
AR 1965 (Annual Report: Board members; committees members; officers; establishments & directors; Chairman's review; research programs in 1965; research highlights; expenditures by areas and disciplines)
1966 (Annual Report: Board members; committees members; officers; establishments & directors; Chairman's review; research programs in 1966; research highlights; expenditures by areas and disciplines)
A 3 (brief history)
73 (current technological research in Atl. area)
75 (field activities in Canadian Arctic, 1965)

Fishing, sport (*see* Angling)

Fishing methods (*see also* Apparatus; Gear; Trawl; etc.)
J 24(3): 689 (shrimp pot for experimental fishing)
B 157: 35, 39 (for lobsters)
161: 35 (for goldeye)
CNG 81 (new hydraulic digging method for butter clams)
A 18 (unexploited)
45, 48 (for Pac. salmon)
47 (for lingcod)
50 (B.C. shrimps)
67 (bluefin tuna)

Fishmeal (*see also* Feedstuff)
J 24(6): 1219, 1291 (freshwater fish)
CHN 29 (capacities of E Canadian plants producing)
CVG 37 (preservation of B.C. summer herring on vessel)

Flagellate
S 1139 (*Discoasteromonas* new species)

Flatfish (*see also* Groundfish; *also* names of species)

CNG 79 (catches by Canada, U.S.A., U.S.S.R., & Japan in NE Pac.)
82 (1966 Hecate Strait exploratory fishing catches)
CNS 28 (Canadian & U.S. trawl catches off B.C., 1954–65)
A 37 (B.C. & U.S. landings, 1956–63, & fisheries potential)
60 (same as CNG 79 above)

Flatworm (*Dugesia dortocephala*)
J 24(11): 2467 (measuring organic feed retained by)

Flavobacterium species
J 24(1): 9 (in fresh lake whitefish)
S 1165 (on stream-incubated pink salmon eggs)

Flavour (*see also* Quality of fishery products)
A 15, 41 (nature of, in flesh foods)

Flemming, Carol Winifred
J 24(2): 443 (serological differences between 2 Atl. coast oysters)
S 1140 (pseudomonad from rainbow trout)

Flesh (*see also* Fillets; Muscle; Protein; Quality; Steaks)
A 15 (nature of flavour, in foods)

Flies, black (Simuliidae) (*see also* Fly)
J 24(4): 769, 823 (affected by N.B. forest insecticide sprays, re their role as salmon & trout feed)

Flounder, arrowtooth (*Atheresthes stomias*) (Pacific turbot)
CNG 79 (Japanese catches in N Pac., 1963–66)
82 (1966 Hecate Strait exploratory fishing catches)
A 46, 51(F) (brief description)
60 (same as CNG 79 above)

Flounder, Bering (*Hippoglossoides robustus*)
A 75 (range extension to central Canadian Arctic)

Flounder, blackback (*see* Plaice, American)

Flounder, starry (*Platichthys stellatus*)
J 24(12): 2515 (stomach contents of adult)
CNS 28 (Canadian & U.S. trawl catches off B.C., 1954–65)

Flounder, winter (*Pseudopleuronectes americanus*)
J 24(2): 357 (α-tocopherol & lipids in tissues of unfed held)
A 43 (1965 Canadian ICNAF studies)

Flounder, witch (*Glyptocephalus cynoglossus*) (graysole; witch)
A 43 (1965 Canadian ICNAF studies)

Flounder, yellowtail (*Limanda ferruginea*)
A 43 (1965 Canadian ICNAF studies)

Flounders in general (*see also* Flatfishes; Groundfish)
CNG 79 (Japanese catches in N Pac., 1963–66)
A 12(F), 65 (fillets weight gain & loss during processing & storage)
60 (same as CNG 79 above)

Flour, fish (*see* Protein concentrate)

Flow (*see* Current; Dilution effect; Tide)

Flury, Jann
J 24(12): 2637 (portable recompression chamber)

Flux, John Etheridge Cormack
J 24(1): 191 (trout response in electric fields)

Fly, house (*Musca domestica*) (*see also* Flies)
J 24(11): 2497 (for assay of insect moult-hormone activity of Japanese yew extract)
S 1146 (oxidase–peroxidase system in)

Foley, Diane Mary
J 24(11): 2339 (lobster muscle weight)

Follett, Wilbur Irving
J 24(5): 1067 (terminology of lamprey teeth)

Food of animals (*see* Feed; Feedstuff)

Forecast
CNG 78 (B.C. Pacific cod fishery for 1967)
80 (B.C. herring abundance)
A 17, 53 (N American fishery potential)
19 (pink & chum salmon runs by high-seas tagging)
33 (for Canadian lobster industry favorable)

Formaldehyde
CVG 37 (for preserving herring on vessel before reduction)
S 1152 (isolation from betaine, dimethyl glycine, & sarcosine oxidation)

Forrester, Clifton Roger
J 24(3): 691 (shrinkage in groundfish)
CNS 28 (B.C. trawl production, 1954–65)

Fraser, Doris Isabel
J 24(2): 221 (radiation on storage of cooked lobster)
(8): 1837 (postmortem cod muscle)

Fraser River, B.C.
S 1120 (tracing estuarial currents by aerial photography)

FRB (Nanaimo)
A 7 (F) (Pac. salmon)
20 (B.C. clams)

21 (Pacific blackcod)
22 (Pacific herring)
23 (Pacific gray cod)
44 (albacore)
45 (sockeye salmon)
46 (Pac. soles & flounders)
47 (lingcod)
48 (coho salmon)
49 (Pacific blackcod)
50 (B.C. shrimp fishing)
51 (F) (Pac. soles & flounders)
54 (F) (albacore)
63 (chum salmon)
70 (eulachon, anchovy, & pilchard)
71 (F) (northern anchovy)
72 (pilchard)

FRB (St. Andrews)
A 10(F) (sea scallop)
13(F) (smelt)
64 (sea scallop)

Freeman, Harry Cleveland
J 24(1): 205 (1α-hydroxycorticosterone)
S 1116 (cortisol binding in Atlantic salmon plasma)

Freeze-drying
J 24(6): 1413 (oysters & clams for total solids assay re condition)
(7): 1461 (Atlantic cod steaks)

Freezing (*see also* Refrigeration; Thawing)
B 160 (tuna by salt-fortified refrigerated sea water in vessel holds)
A 27 (Nfld. trap-caught cod at sea)
41 (brine-spray freezing tuna at sea)
42 (fish freezer for Eskimo fishermen)

Freshwater fish products (*see also* names of freshwater fishes)
J 24(1): 9 (whitefish preservation by gamma irradiation)
(6): 1219 (oil yield & composition of 4 species)
(6): 1291 (composition & nutritive value of meals)
(11): 2229 (hypoxanthine formation in muscle of iced flesh)
B 158 (re economics of Mackenzie District, N.W.T., fisheries)
A 6(F) (marinated fillets)

Frick, Harold Clay
B 157 (Canadian lobster fishery)

Friedlaender, Carlo Gotthelf Immanuel
S 1161 (rock salt bacteriological investigation)

Frostfish (*Benthodesmus simonyi*)
J 24(10): 2201 (in line fishing from ocean weathership P; identity doubtful)

Fry (*see* names of adult fishes, e.g. Trout; Salmon)

Fucoxanthin (*see* Pigments)

Fucus species (*see* Rockweeds)

Fukuda, Y.
S 1129 (N Pac. Ocean salmon)

Fulton, John Douglas
S 1172 (phytoplankton blooms)

Fundulus diaphanus (*see* Killifish, banded)

Fundy, Bay of
S 1150 (effect of light on herring movements)

Fungus
J 24(4): 843 (*Dermocystidium* on prespawning adult chinook salmon)

Fur (*see* Pelage; Pelts)

G

Gadidae (*see also* names of species)
J 24(6): 1315 (cranial osteology re specialization development)

Gadus macrocephalus (*see* Cod, Pacific)

Gadus morhua (*see* Cod, Atlantic)

Gadus ogac (*see* Cod, Greenland)

Gaffkya homari; *G. tetragena*
J 24(12): 2323 (susceptibilities to disinfectants & antibiotics re Atl. lobster disease)

Gaidius columbiae
J 24(2): 231 (new copepod species, B.C.)

Garrod, David John
J 24(1): 145 (Arcto-Norwegian cod population dynamics)

"Gas bubble" disease
J 24(4): 867 (histopathology, in Pac. salmon fingerlings)

Gases
S 1154 (apparatus for sampling, from bottom sediments)

Gasterosteus leiurus (*see* Stickleback, threespine (freshwater))

Gasterosteus trachurus (*see* Stickleback, threespine (marine))

Gastropoda (*see also* subclassifications)
S 1128 (in benthos of 4 Lake Superior bays)

Gear fishery (*see also* Apparatus; Fishing methods; Net, gill; Selectivity of fishing gear; Trawl; etc.)
J 24(3): 689 (shrimp pot)
(6): 1275 (longline for pelagic redfish)
CNG 82 (trawl & longline for exploratory B.C. groundfish fishing)

S 1176 (relative efficiency & selectivity of 3 types of scallop drags)
A 61(F) (underwater photography for tracing fish movements into)
74 (same as CNG 82 above)

Geiger, Shirley Evelyn
J 24(2): 243 (flesh of salmon)
A 29 (fish in rigor mortis in refrigerated sea water)

Gempylidae (*see Neolotus*)

Genetics
J 24(12): 2613 (genetic control in sockeye salmon fry lakeward migrations)

Genital system (*see also* Eggs, fish; Hormones; Milt; Ovary; Testes)
J 24(2): 447 (anatomy, in trouts)

Geoduck (clam) (*Panope generosa*)
A 20 (B.C.)

Geology
J 24(11): 2241 (bottom lithology, Kouchibouguac Bay, N.B.)

Georgia, Strait of (*see also* Oceanography, B.C. coast)
J 24(11): 2455 (larval herring in July 1966)
A 2 (B.C. Pacific cod trawl fishery)

Georgian Bay, Lake Huron, Ont.
J 24(4): 887 (rainbow trout phenotypic characteristics)
(12): 2539 (lamprey parasitism on rainbow trout)

Gilgan, Michael Wilson
J 24(11): 2497 (Japanese yew extract)

Gillespie, Gerald J.
A 11(F) (hormones in skate blood plasma)
66 (lobster diet)

Gills; Gill rakers (*see also* Net, gill; Respiration; Selectivity of fishing gear)
J 24(4): 843 (fungus attack on chinook salmon)
(5): 965 (raker development in lake trout)
(6): 1407 (rakers re lake trout populations morphology)
(8): 1637 (counts of allopatric marine & freshwater sticklebacks & their hybrid)
(9): 1999 (plasticity of number & length in sockeye salmon)
(11): 2355, 2448 (mathematical treatment of gill surface re body surface & metabolic rate)

Globicephala melaena (*see* Whale, pilot)

Glossary
B 156: 126 (of economics terminology re Canadian lobster fishery)

Glucose (*see also* Sugars)
J 24(5): 939 (effects of partial descaling & desliming on rainbow trout blood)
(8): 1701 (effects of disturbance on rainbow trout metabolism)
S 1110 (re algae photosynthesis)

Glycerides (*see* Triglycerides; *also* Acids, fatty; Lipids; Oils & fats)

Glycogen; Glycolysis (*see also* Carbohydrates)
J 24(3): 651 (re *p*H, etc. in postmortem unfrozen Atlantic cod)
(5): 939 (effects of partial descaling & desliming on rainbow trout liver metabolism)
(8): 1701 (effects of disturbance on rainbow trout liver)
(8): 1837 (in postmortem relaxed Atlantic cod muscle)
S 1117 (review of postmortem changes in fish muscles)
A 30 (enzymic degradation in fish muscle)

Glyoxalate
S 1135 (metabolism by Atlantic salmon & cod sperm)

Glyptocephalus cynoglossus (*see* Flounder, witch)

Glyptocephalus zachirus (*see* Sole, rex)

Gnathophausia gracilis
J 24(5): 1101 (fatty acids composition)

Goby, bluespot (*Coryphopterus nicholsi*)
J 24(2): 433 (scale regeneration)

Godfrey, Harold
S 1129 (N Pac. Ocean salmon)

Goldeye (*Hiodon alosoides*)
B 161 (biology; feed; parasites; fishery; processing; management; etc., in Canada)

Goldfish (*Carassius auratus*)
J 24(3): 695 (blood low-mobility proteins)
(6): 1419 (ammonia in excreta)
(11): 2395 (oxygen consumption mathematics)

Gonads (*see* Eggs, fish; Hormones; Milt; Testes)

Gonyaulax species (protozoan dinoflagellates)
J 24(7): 1589 (growth & toxicity; comparison of *G. catenella* & *G. tamarensis* toxins)
CNG 75 (*G. catenella* & *G. acatenella* as causes of occasional shellfish toxicity on B.C. coast)

Grading (*see also* Quality of fishery products)
J 24(6): 1203 (significance of bound oil in stored canned sockeye salmon)

(7): 1613 (canned Pac. salmons for colour)
A 31 (preliminary quality tests of cod & haddock with Intelectron Fish tester)

Grant, Charles David
J 24(4): 823 (phosphamidon effects on aquatic insects)

Grayling, arctic (*Thymallus arcticus*)
A 14 (re Great Bear Lake, N.W.T., sport fishing)

Graysole (*see* Flounder, witch)

Great Bear Lake, N.W.T.
S 1191 (nannoplankton of marine origin in)
A 14 (history; description; hydrography; limnology; fisheries)
75 (1965 limnology & fish study)

Great Lakes (*see* Georgian Bay; South Bay; *also* names of individual Great Lakes)

Great Slave Lake, N.W.T.
J 24(2): 299 (Catostomidae speciation)
B 158 (physical & economic organization of fisheries)

Greenland
J 24(4): 833 (echinoderms from drifting ice island off E coast)
S 1126 (salmon fishery effects on N.B. salmon stocks & fishery)
A 25 (recovery of Canadian-tagged salmon near)

Grey (*see* Gray)

Gribble (*Limnoria* species)
J 24(2): 261 (estimating attack on wood)

Grilse (*see* Salmon, Atlantic)

Groot, Cornelis
S 1166 (sockeye orientation)

Groundfish (Pacific) (*see also* names of species)
J 24(3): 691 (shrinkage factor in measuring)
CNG 79 (recent developments in NE Pac. fishery)
82 (exploratory fishing in Hecate Strait & Dixon Entrance, 1966)
CNS 28 (Canadian & U.S. trawl catches off B.C., 1954–65)
A 37 (potential)
60 (same as CNG 79 above)
74 (summary of CNG 82 above)

Growth (*see also* Development)
J 24(1): 87 (adult smallmouth bass re temperature)
(2): 305 (*Ampelisca* amphipod sibling pairs)
(3): 475 (juvenile largemouth bass re oxygen concentration)
(5): 1077 (American plaice in Nfld. area)
(6): 1209 (& hypothetical age of Nfld. bait squid)
(7): 1589 (& toxicity of *Gonyaulax tamarensis*)
(10): 2117 (tagged white suckers)
(11): 2355, 2407, 2420, 2428, 2436 (mathematical model for fishes)
(12): 2595 (effects of tagging vs. marking on young Atlantic salmon)
(12): 2573 (& age of Atlantic cod in Ogac Lake, Baffin Is.)
B 157: 14 (lobster)
161: 6 (goldeye)
S 1134 (Atlantic oyster in hatcheries)
1155 (plankton, determined by electronic particle size enumerator)

Guanine (*see* Purines)

Guano
J 24(6): 1299 (of gulls causing guanotrophy of a small lake)

Gull, black-headed (*Larus ridibundus*)
J 24(6): 1299 (probable cause of guanotrophy of a small lake)

Guppy (*Lebistes reticulatus*)
J 24(11): 2414, 2436 (mathematics of weight loss of fasting; also of growth)

Gushue, Wilfred George
J 24(7): 1613 (colour in grading canned salmon)

Guttmann, Abraham
J 24(4): 895 (isopropyl alcohol preservation of fish protein concentrate raw material

Gymnaster pentasterias (a dinoflagellate)
S 1191 (in Great Bear Lake, N.W.T.)

H

Haddock (*Melanogrammus aeglefinus*)
S 1147 (distribution off E Canada coast re season, depth, & bottom temperature)
1158 (heterogeneity in length & age compositions of commercial landings)
1160 (trend-interpreting difficulties in landings from E Scotian Shelf)
1185 (fishery trends in ICNAF Subarea 3)
A 31 (quality assessment by Intelectron Fish Tester)
43 (1965 Canadian ICNAF studies)

Haefner, Paul Aloysius, Jr.
J 24(7): 1553 (Penobscot R. estuary hydrography)

Hagen, Donald Warren
J 24(8): 1637 (isolating mechanisms in *Gasterosteus*)

Hagfish, black (*Eptatretus deani*) (*Polistotrema deani*)
J 24(5): 1101 (fatty acids composition)

Hair (*see* Pelage; Pelts; Seal)

Hake, Pacific (*Merluccius productus*)
J 24(8): 1763 (host to new trematode species)

Hake, silver (*Merluccius bilinearis*)
J 24(6): 1315 (cranial osteology)
A 43 (1965 Canadian ICNAF studies)

Hake, squirrel (*Urophysis chuss*)
J 24(6): 1315 (cranial osteology)
A 43 (in Canadian ICNAF area)

Halibut, Atlantic (*Hippoglossus hippoglossus*)
J 24(1): 53 (sizes at maturity, spawning season; feed)

Halibut, Greenland (*Reinhardtius hippoglossoides*) (turbot)
J 24(12): 2563 (composition of low-iodine-value fatty acids)
CHN 30 (discolored flesh problem in gillnetted)
A 43 (1965 Canadian ICNAF studies)

Halibut, Pacific (*Hippoglossus stenolepis*)
CNG 82 (1966 Hecate Strait exploratory fishing catches)
A 30 (enzymic degradation of muscle glycogen & adenosine phosphate re quality)

Halichoerus grypus (*see* Seal, gray)

Halocline (*see also* Oceanography)
J 24(11): 2207 (annual changes in E subarctic Pac. Ocean)

Handling
A 10(F), 64 (of sea scallops)
41 (review of researches on fish)

Handsawfish (*see* Lancetfish (Pacific))

Hanson, Arthur John
J 24(9): 1955 (sockeye mate selection)

Harrison, John Stanley Milton
B 160 (chilling and freezing salmon and tuna in refrigerated sea water)

Hart, John Lawson
J 24(11): 2485 (lingcod fecundity)
A 39 (American smelt)
43 (Canadian ICNAF research Subareas 1–5)

Hartman, Wilbur Lee
J 24(10): 2069 (sockeye migratory behavior)

Hatchery
J 24(1): 77 (behaviour of pink salmon fry in & after holding in a tank)
(2): 281 (returns of marked trout reared in)
(5): 1117 (vs. natural propagation of sockeye salmon re stamina)
CSG 51 (progress in development of E Canadian oyster)
S 1134 (procedure developments for Atlantic oysters)
A 57(F) (brook, brown, & rainbow trout in Canadian Maritimes)

Hayes, Frederick Ronald
J 24(9): 1979 (Edgar Clark Black obituary)

Healey, Michael Charles
J 24(11): 2321 (pink salmon marine migration)

Heard, William R.
J 24(10): 2069 (sockeye migratory behavior)

Hearing (*see* Sound, reactions to)

Heart (*see also* Blood)
J 24(8): 1701 (rainbow trout disturbance effects on)
(8): 1775 (cardiovascular dynamics in swimming sockeye salmon adults)
(8): 1819 (electrocardiogram for testing lampricide vs. anoxia effects on sea lamprey)
(11): 2309 (Atlantic cod electrocardiogram re audiogram)

Heat budget and exchange in waters (*see also* Limnology; Oceanography)
B 156: 19, 56 (Dixon Entrance, B.C.)

Hecate Strait, B.C. (*see also* Oceanography, B.C. coast)
B 156 (physical oceanography, re Dixon Entrance)
CNG 76 (shrimp exploration)
82 (exploratory groundfish fishing, 1966)
A 2 (B.C. Pacific cod trawl fishery)
74 (summary of CNG 82 above)

Hemoglobin (*see* Blood)

Hemolymph (*see* Blood)

Henderson, Nancy Elizabeth
J 24(2): 447 (urinary and genital systems of trout)

Hepatopancreas
J 24(11): 2339 (of lobster re muscle weight, serum proteins, & hemocytes)

Heritage, George Dwight
CNG 76 (Hecate Strait and Queen Charlotte Sound shrimp)

Herring, Atlantic (*Clupea harengus*)
J 24(12): 2563 (composition of low-iodine-value fatty acids)

S 1149 (Magdalen Is. fishery re sea temperatures)
1150 (effect of light on movements)
1189 (oil fatty acids composition & structure)
A 8(F) (description; life history; Canadian fishery; age determination)
43 (1965 Canadian ICNAF studies)

Herring, lake (*Coregonus artedii*; *C. sardinella*) (*see also* Cisco; Tullibee)
A 14 (Great Bear Lake, N.W.T.)

Herring, Pacific (*Clupea pallasii*)
J 24(8): 1833 (botulinum spore germination in tissue extracts)
(11): 2455 (larval occurrence in Strait of Georgia)
CNG 77, 83 (spawn abundance, B.C. 1966; 1967)
80 (recent B.C. abundance changes & 1967–69 forecast)
CVG 37 (preservation of summer, aboard fishing vessel)
A 22, 36 (history, development, biology, location, distribution, management, technology, etc. of B.C. fishery)
59 (1966 B.C. spawning lowest on record)
62 (same as A 59 above)

Heuristic data analyses
B 156 (Dixon Entrance, B.C., physical oceanography)

Hines, James Alexander
J 24(8): 1717 (cod muscle enzyme)
(8): 1837 (postmortem cod muscle)

Hingley, Helen Joyce
J 24(2): 457 (blackberry in cod)
(7): 1521 (isopropyl alcohol in fish protein)

Hiodon alosoides (*see* Goldeye)

Hippoglossoides platessoides (*see* Plaice, American)

Hippoglossoides robustus (*see* Flounder, Bering)

Hippoglossus hippoglossus (*see* Halibut, Atlantic)

Hippoglossus stenolepis (*see* Halibut, Pacific)

Hirudinea
S 1128 (in benthos of 4 Lake Superior bays)

Histology (*see also* Cytology)
J 24(1): 67 (sexually maturing sockeye salmon thyroid, kidney, & pancreas)
(2): 435 (E Pac. harbour seal hair follicles)
(3): 679 (tumor-like growth on freshwater mussel foot)
(4): 843 (chinook salmon gills attacked by fungus)
(4): 867 (various tissues of salmon having "gas bubble" disease)
(8): 1791 (sockeye salmon pituitary gland)
(9): 1985 (hydroid parasitic on blue lanternfish)
(9): 2003 (new Bryozoa species *Figularia quaylei*)
(9): 2007 (snout tumor on snake prickleback)
(11): 2339 (lobster hepatopancreatic tissue)
(12): 2549 (Atlantic cod white striated myotomal muscle)
S 1140 (rainbow trout bacterial skin lesions)
1181 (Ceriantharia nerve cells)
1187 (rainbow trout tissues re hypophysectomy)

History (*see also* Life history)
B 157: 1, 104 (Canadian lobster fishery, re economics)
158: 7 (of Mackenzie District, N.W.T., fisheries)
CNG 75 (shellfish poisoning in B.C.)
A 3 (brief, of Fisheries Research Board of Canada)
14 (Great Bear Lake, N.W.T., re fisheries)
36 (herring, Pac. coast)

Hodder, Vincent Mackay
S 1185 (ICNAF Subarea 3 haddock fishery trends)

Hogsucker (*Hypentelium nigricans*)
J 24(3): 695 (blood low-mobility proteins)

Holothorians (*see* Sea cucumbers)

Homarus americanus (*see* Lobster)

Homing (*see also* Migration)
J 24(10): 2011 (re olfaction & vision in cutthroat trout)

Hope, Eric Lorne Victor
J 24(5): 1155 (digitized baththermograph aperture cards)

Hormones (*see also* Cortisol)
J 24(1): 205 (mineralocorticoid activity of skate blood hydroxycorticosterone for rat)
(8): 1823 (ovine prolactin effect on hypophysectomized eel osmoregulation)
(11): 2497 (insect moult-hormone activity of extract from Japanese yew branches)
S 1114, 1141, 1167, 1168 (in skate peripheral plasma or interrenal tissue)
1121 (steroid destruction during silica-gel chromatography)
1131 (in vitro biosynthesis by Atlantic salmon gonad materials)

1167, 1168 (in vitro biosynthesis of 1α-hydroxycorticosterone by skate tissues)
A 11(F) (hormones isolated from skates blood plasma)

Horse, domestic (*Equus caballus*)
S 1190 (population on Sable Is., N.S.)

Houck, Warren Jacob
J 24(12): 2503 (Cuvier's beaked whale)

Hourston, Alan Stewart
J 24(12): 2527 (stock exploitation)

Houston, Arthur Hillier
J 24(11): 2267 (trout hematology)

Hoyle, Richard James
J 24(3): 607 (seasonal changes in cod condition and lipid content)
S 1118 (polar bear and seal fatty acids)
1186 (dietary triglyceride conversion)

Huang, Pei Chu
S 1118 (polar bear and seal fatty acids)

Hudson Bay
J 24(9): 1873 (decapod Crustacea from *Calanus* collections, 1953, 1954, 1958–61)

Humphreys, Robert David
A 8(F) (Atlantic herring)
9(F) (Atlantic mackerel)

Humphreys, Robert Murray
J 24(7): 1573 (sockeye and pink ova and sperm fertility)

Hunt Creek, Michigan
J 24(7): 1425 (brook trout population studies over 14 years)

Hunter, John Gerald
A 75 (FRBC in Arctic in 1965)

Huron Lake (*see* Georgian Bay; South Bay)

Hybrids; Hybridization
J 24(3): 495 (absence in pond with bluegill & pumpkinseed)
(8): 1637 (re marine & freshwater threespine sticklebacks)

Hydra (coelenterates)
A 14 (Great Bear Lake, N.W.T.)

Hydrichthys
J 24(9): 1985 (epizoic on myctophid fishes & on their parasitic copepods)

Hydrogen sulphide (*see* Sulphur compounds; Thetin derivatives)

Hydrography (*see also* International Commission for the Northwest Atlantic Fisheries; Oceanography)
J 24(3): 555 (Tanquary Fjord, Ellesmere Is., Canada Arctic)
(5): 981 (Ogac Lake, Baffin Is.)
(7): 1553 (Penobscot R. estuary, Maine)
(11): 2241 (Kouchibouguac Bay, N.B.)
S 1127 (Labrador Sea, Davis Strait, S Baffin Bay)
A 14 (Great Bear Lake, N.W.T.)
43 (ICNAF 1965 Canadian research in Subareas 1–5)

Hydroid
J 24(9): 1985 (*Hydrichthys* sp. epizoic on myctophid fishes & on their parasitic copepods)

Hydrolagus colliei (*see* Ratfish)

Hypentelium nigricans (*see* Hogsucker)

Hyperprosopon anale (*see* Surfperch, spotfin)

Hyperprosopon argenteum (*see* Surfperch, walleye)

Hypomesus pretiosus (*see* Smelt, surf)

Hypophysectomy (*see* Pituitary)

Hypoxanthine (*see* Purines)

Hyslop, William Frank
J 24(10): 2137 (kraft mill effluent in B.C. harbour)

I

Ice; Icing
A 26 (containing antibiotics for preserving fish quality)
41 (review of)

Ichthyomyzon
J 24(5): 1067 (in lampreys key)

Ichthyomyzon unicuspis (*see* Lamprey, silver)

ICNAF (*see* International Commission for the Northwest Atlantic Fisheries)

Ictalurus melas (*see* Bullhead, black)

Ictalurus natalis (*see* Bullhead, yellow)

Ictalurus nebulosus (*see* Bullhead, brown)

Ictalurus punctatus (*see* Catfish, channel)

Ictiobus bubalus (*see* Buffalo, smallmouth)

Ide, Frederick Palmer
J 24(4): 769 (DDT effects on aquatic insects)

Idler, David Richard
J 24(1): 127 (thawing processes effects on cod and redfish)

(1): 205 (1α-hydroxycorticosterone)
(3): 651 (postmortem changes in cod)
S 1114 (skate plasma testosterone)
1116 (cortisol binding in Atlantic salmon plasma)
1121 (steroid destruction by thin-layer chromatography)
1131 (Atlantic salmon biosynthesis of 11-ketotestosterone and 11β-hydroxytestosterone)
1141 (*Raja* 1α-hydroxycorticosterone)
1167 (1α-hydroxycorticosterone biosynthesis)
1168 (1α-hydroxycorticosterone synthesis in vitro)
A 27 (Nfld. trap cod)

Illex illecebrosus illecebrosus (*see* Squid, short-finned)

Illumination (*see* Light, reactions to)

Imikpuk Lake, Alaska
J 24(9): 1861 (phytoplankton dynamics in arctic lake)

Immunity
J 24(4): 769 (natural or acquired, of certain aquatic insects against insecticides)

Inconnu (*Stenodus leucichthys*)
B 158 (in economics of N.W.T. commercial fisheries)
A 14 (Great Bear Lake, N.W.T.)

Indian Arm, B.C.
J 24(1): 33 (algae vertical distribution re environment)

Inlets, Fjords (*see also* Indian Arm; Saanich Inlet; Tanquary Fjord)
J 24(7): 1475 (oceanography of larger SE Alaskan)
(11): 2207 (annual changes in waters of B.C.)

Insecticides
J 24(4): 701, 709, 731, 769, 807, 823 (history, research, & management program, effects on insects, salmon, & trout, etc., re spraying N.B. forests with DDT or phosphamidon to combat spruce budworm infection)
(5): 1173 (formamidin & hexachlorocyclohexane effects on young coho salmon)

Insects, aquatic (*see also* Insecticides)
J 24(4): 769, 807, 823 (affected by spraying N.B. forests with DDT or phosphamidon)

Insects, non-aquatic (*see also* Fly, house; Flies, black)
J 24(11): 2497 (moult hormone activity of extract from Japanese yew branches)
S 1146 (oxidase–peroxidase system in various)

International Commission for the Northwest Atlantic Fisheries (ICNAF)
S 1126 (Greenland salmon fishery influence on N.B. salmon fishery & stocks)
1127 (Labrador Sea & Davis Strait hydrography, 1965)
1142 (Scotian Shelf waters long-term temperature variations)
1143 (forecasting surface water temperatures at St. Andrews, N.B.)
1147 (haddock distribution off E Canada coast)
1148 (variation in cod recruitment re sea temperatures)
1149 (Magdalen Is. herring fishery re sea temperatures)
1150 (effect of light on Bay of Fundy herring movements)
1158 (heterogeneity of length & age composition in commercial groundfish landings)
1160 (trend-interpreting difficulties re cod & haddock landings from E Scotian Shelf)
1185 (haddock fishery trends)
A 43 (report on 1965 Canadian research in Subareas 1–5)

International North Pacific Fisheries Commission (INPFC)
S 1129 (sockeye salmon distribution in N Pac. Ocean)
1137 (salmons longline fishing, tagging, racial studies, oceanography, 1965)
1156 (pink salmon distribution in N Pac. Ocean)

Interrenal tissue
S 1167, 1168 (in vitro biosynthesis of 1α-hydroxycorticosterone by skates)

Invertebrates (*see also* names of classifications and of species)
J 24(11): 2467 (measuring organic feed retention by aquatic)
A 1 (research on Nfld. commercial marine)

Iodine value (*see* Acids, fatty)

Iredale, David Gordon
A 6(F) (sweet cured freshwater fish slices)

Irminger Sea (east of Greenland)
J 24(12): 2639 (Atlantic salmon catches re Europe–Greenland migration)

Iron compounds
A 73 (catalyzing fish flesh oxidative rancidity)

Irradiation
J 24(1): 9 (lake whitefish preservation by gamma)
(2): 221 (cooked lobster meat preservation by gamma)

Ishida, Teruo
S 1156 (N Pac. pink salmon)

Isopoda (*see also* Gribble)
J 24(10): 2161 (*Livoneca* parasitic on surf-perches)
S 1128 (in benthos of 4 Lake Superior bays)

Isotopes (other than ^{14}C)
J 24(1): 9, (2): 221 (^{60}Co for preservative gamma irradiation)
S 1131, 1186 (^{3}H in tracing hormone or fat biosynthesis)

J

Jaffray, June I.
J 24(3): 651 (postmortem changes in cod)

Jangaard, Peter Michael
J 24(3): 607 (seasonal changes in cod condition and lipid content)
(3): 613 (seasonal changes in cod fatty acid composition)
(4): 895 (isopropyl alcohol preservation of fish protein concentrate raw material)
S 1177 (cod liver lipids fatty acid esters)
CHN 28 (care and treatment of seal pelts)
29 (fish meal plants in E Canada)
31 (frozen storage of whole lobsters)
A 55 (whole lobster frozen storage)

Javaid, M. Yaqub
J 24(7): 1507 (*Salmo salar* and *S. gairdneri* temperature selection)
(7): 1515 (starvation on salmonid selected temperature)

Jaw
S 1188 (length re *Phoca vitulina* seal subspecies)

Jenkinson, Donald William
CNS 25 (B.C. sockeye catches, 1912–63)

Jensen, Jens Møller
J 24(12): 2639 (Irminger Sea Atlantic salmon)

Johannes, Robert Earl
J 24(11): 2467 (aquatic invertebrate retention)

Johnson, Lionel
S 1191 (Great Bear Lake nannoplankton)
A 14 (Great Bear Lake)

Johnston, Charles Edward
J 24(5): 955 (purines in parr–smolt Atlantic salmon)

Jonas, Richard Edmund Ernest
J 24(2): 273 (compounds in rainbow trout muscle)
(12): 2555 (trout muscle phospholipase A activity)

K

Kabata, Zbigniew
J 24(3): 515 (morphology of *Phrixocephalus cincinnatus*)

Kalamalka Lake, B.C.
J 24(2): 463 (introduction of *Mysis relicta* as trout feed)

Kalff, Jacob
J 24(9): 1861 (arctic lake phytoplankton dynamics)

Kamra, Saroja Keshav
CHN 30 (discoloured flesh in gillnet turbot)

Karluk, Alaska
J 24(12): 2613 (sockeye salmon fry lakeward migrations)

Ke, Paul Jenn
J 24(12): 2563 (Canadian marine oils)

Keenleyside, Miles Hugh Alston
J 24(3): 495 (sunfish reproductive isolation)
(4): 807 (DDT effects on young Atlantic salmon food)

Keewatin District, N.W.T.
B 158: 65 (commercial fisheries)

Kelly, Joanne Megan
J 24(8): 1833 (*Clostridium botulinum* type E in fish and shellfish extracts)

Kelps (*see also* Algae; Photosynthesis; Seaweeds)
J 24(1): 33 (vertical distribution re environment, Indian Arm, B.C.)

Kennedy, William Alexander
B 161 (goldeye in Canada)

Kerr, Roberta Helen
J 24(2): 299 (Catostomidae electropherograms)

Kerswill, Charles James
J 24(4): 701 (introduction and summary to insecticide sprayings)
(4): 709 (fish losses after insecticide sprayings)
A 25 (Atlantic salmon near Greenland)

Ketchen, Keith Stuart
CNG 78 (review and 1967 forecast of Pacific cod trawl fishery)
79 (domestic and foreign fishery of groundfish)
A 2 (Pacific cod trawl fishery)
37 (groundfish potential)
60 (groundfish in NE Pac.)

Key
J 24(5): 1067 (to lamprey genera, based on teeth)

Keyhole Lake, Victoria Is. (Canadian Arctic)
A 75 (limnology & fish study, 1965)

Keyte, Freeman Kilbourne
J 24(11): 2491 (computer vs. manual calculations)

Kidney
J 24(1): 67 (effect of feeding on, in sexually ripening sockeye salmon)
(8): 1701 (rainbow trout disturbance effects on)

Kilambi, Raj Varad
J 24(3): 629 (parasites among surf smelts)

Killifish, banded (*Fundulus diaphanus*)
S 1132 (predation by birds, Crecy Lake, N.B.)

Kimball, Nadine Ruth
S 1121 (steroid destruction by thin-layer chromatography)

King, George Robert
J 24(2): 281 (hatchery-reared trout returns)

Kodiak Island, Alaska
J 24(12): 2627 (king crab breeding off)

Kohler, Allan Carl
J 24(1): 53 (biology of Atlantic halibut)
S 1148 (cod recruitment)

Kokanee (*Oncorhynchus nerka*) (landlocked sockeye salmon)
J 24(2): 463 (*Mysis relicta* introduced in lakes as feed)
(9): 1955 (mating selection, Babine Lake, B.C.)

Kouchibouguac Bay, N.B.
J 24(11): 2241 (bedrock & sediments of)

Kranck, Kate
J 24(11): 2241 (Kouchibouguac Bay bedrock and sediments)

Krill (zooplankton feed of whales)
S 1110 (fatty acids of *Meganyctiphanes norvegica* re fin whale fatty acids)

Kühn, Robert
S 1161 (rock salt bacteriological investigation)

L

Labrador Sea
J 24(6): 1275 (pelagic adult redfish)
(7): 1531 (cod fecundity)

Lactate
J 24(5): 939 (effects of partial descaling & desliming on rainbow trout glycolysis)
(8): 1837 (in postmortem relaxed Atlantic cod muscle)

Lakes (*see* Limnology; Waters, natural; *also* names of individual lakes)

Lakes, tidal
J 24(5): 975, 981, (12): 2573 (Ogac & nearby lakes, Baffin Is., biology, hydrography, chemistry)

Laminaria (*see* Kelps; Seaweeds)

Lamna ditropis (*see* Shark, salmon)

Lamna nasus (*see* Porbeagle)

Lampanyctus leucosparus (*see* Lanternfish, smallfin)

Lampetra
J 24(5): 1067 (in lampreys key)

Lampetra lamottei (*see* Lamprey, American brook)

Lamprey, American brook (*Lampetra lamottei*)
J 24(6): 1269 (blood protein & muscle myogen electropherograms of ammocoete & adult)
S 1128 (in 3 Lake Superior bays)

Lamprey, sea (*Petromyzon marinus*)
J 24(6): 1269 (blood protein & muscle myogen electropherograms of landlocked ammocoete & adult)
(8): 1819 (comparative effects of a lampricide vs. anoxia)
(10): 2117 (effects on a Lake Huron white sucker population)
(12): 2539 (parasitic on Georgian Bay rainbow trout)
S 1128 (in 4 Lake Superior bays)

Lamprey, silver (*Ichthyomyzon unicuspis*)
J 24 (6): 1269 (blood protein & muscle myogen electropherograms of ammocoete & adult)

Lampreys (genera only)
J 24(5): 1067 (teeth; key to, based on teeth)
S 1128 (in 4 Lake Superior bays)

Lampricide (*see* Toxicants for fishes)

Lancetfish (Pacific) (*Alepisaurus borealis*) (handsawfish)
J 24(10): 2201 (in line fishing from ocean weathership P)

Landings (*see* Catches)

Lanternfish, blue (*Tarletonbeania crenularis*)
J 24(9): 1985 (host of hydroid *Hydrichthys* & a parasitic copepod)

Lanternfish, smallfin (*Lampanyctus leucosparus*)
J 24(9): 1985 (host of hydroid *Hydrichthys* & a parasitic copepod)

Lanternfish, theta (*Diaphus theta*)
J 24(9): 1985 (host of hydroid *Hydrichthys* & a parasitic copepod)

Lanternfishes (*Scopelengys tristis*; *Myctophum nitidulum*; *Tripholurus mexicanus*)
J 24(5): 1101 (fatty acids composition)

Lantz, Andrew William
J 24(6): 1219 (freshwater fish oils)
(6): 1291 (freshwater fish meals)
A 6(F) (sweet cured freshwater fish slices)
42 (freezer for Eskimo fishermen)

Larkin, Peter Anthony
J 24(12): 2527 (stock exploitation)
A 16 (summarization of summary of symposium)
17 (N American fishery potential)
18 (challenges facing fisheries science)
53 (N American fishery potential)

Larvae (*see also* name of adult organism)
J 24(4): 883 (plankton sampler for Pacific oyster)
(5): 927 (limnetic, of N Wisconsin lakes freshwater fishes)

Lauder, John Tweedie
A 27 (Nfld. trap cod)

Laurs, Robert Michael
J 24(9): 1985 (hydroid epizoic on myctophid fishes)

Lauzier, Louis Marcel
J 24(9): 1845 (ocean bottom drift)
S 1142 (Scotian Shelf temperature variations)
1143 (St. Andrews, N.B. water temperatures)
1149 (Magdelen Is. herring fishery)

Lebistes reticulatus (*see* Guppy)

LeBrasseur, Robin John
J 24(10): 2201 (ocean station P line fishing)
S 1172 (phytoplankton blooms)

Lecithinase (*see* Enzymes)

Legendre, Rosaire
J 24(7): 1461 (freeze-drying of Atlantic cod steaks)
(8): 1693 (brining light-salted fish)

Length (*see also* Growth; Length–weight ratio; Size)
J 24(1): 87 (smallmouth bass, re temperature)
(3): 691 (shrinkage factor in measuring groundfish)
(7): 1531 (vs. fecundity, Atlantic cod)
(11): 2455 (frequencies of Strait of Georgia herring larvae)
(11): 2481 (pilot whales wintering in Nfld. inshore waters)
S 1158 (heterogeneity in Atlantic cod & haddock commercial landings)

Length–weight ratio (see *also* Length; Size; Weight)
J 24(10): 2117 (in a Lake Huron white sucker population)
(11): 2485 (re lingcod fecundity)
(12): 2573 (Atlantic cod in Ogac Lake, Baffin Is.)
B 161: 18 (goldeye)

Lepidopsetta bilineata (*see* Sole, rock)

Lepomis cyanellus (*see* Sunfish, green)

Lepomis gibbosus (*see* Pumpkinseed)

Lepomis macrochirus (*see* Bluegill)

Lepophidium cervinum (*see* Cusk-eel, fawn)

Lernaeoceridae (*see Phrixocephalus cincinnatus*)

Lethenteron
J 24(5): 1067 (in lampreys key)

Leuroglossus stilbuis (*see* Smoothtongue, California)

Lewis, John Bradley
J 24(3): 683 (dolphin and tuna food)

Lewis, Roger Wolcott
J 24(5): 1101 (marine animal fatty acids)

Li, Ming Fang
J 24(2): 443 (serological differences between 2 Atl. coast oysters)
(11): 2339 (lobster muscle weight)
S 1140 (pseudomonad from rainbow trout)

Life history (*see also* names of other organisms)
J 24(2): 305 (*Ampelisca vadorum* & *A. abdita* amphipods)
B 161 (goldeye)
A 5(F) (lobster)
7(F) (Pac. salmons)
8(F) (Atlantic herring)
9(F) (Atlantic mackerel)
10(F), 64 (giant scallop)
20 (B.C. clams)
21 (sablefish)
22 (Pacific herring)
23 (Pacific cod)
24 (Atlantic salmon)
36 (B.C. herring)
39 (American smelt)
47 (lingcod)
58 (of parasitic cercariae larvae causing "swimmers' itch" on humans)
67 (bluefin tuna)

Light, reactions to (*see also* Diel habits)
J 24(10): 2011 (vision re cutthroat trout homing & orientation)

(11): 2321 (re pink salmon fry early marine migration)
S 1150 (effect on Bay of Fundy herring movements)
1166 (re orientation of seaward-migrating young sockeye salmon)

Lightfishes
J 24(5): 1101 (*Vinciguerria lucetia* & *Argyropelecus lychnus* fatty acids composition)

Limacina (*see* Pteropoda)

Limanda ferruginea (*see* Flounder, yellowtail)

Limnology
J 24(1): 101 (thermal, South Bay, Lake Huron)
(2): 463 (Pinaus & Kalamalka lakes, B.C.)
(6): 1299 (& guanotrophy of a small lake)
(9): 1861 (phytoplankton dynamics in Alaskan arctic lake)
(10): 2045, 2189 (small lakes of Babine Lake, B.C., system)
(11): 2283 (Marion Lake, B.C.)
(11): 2461 (new plastic-bag water sampler)
(11): 2473 (simple model of lake for instructional use)
(11): 2491 (computer vs. manual temperature & depth calculations)
S 1191 (Great Bear Lake, N.W.T.)
A 14 (Great Bear Lake)
75 (Great Bear Lake; Keyhole Lake; Victoria Is., Canadian Arctic, 1965 studies)

Limnoria (*see* Gribble)

Line fishing
CNG 79 (& trawl catches of groundfish off B.C., 1945–65)
82 (& trawl for B.C. groundfish exploratory fishing)
A 74 (same as CNG 82 above)

Ling (*see* Burbot)

Lingcod (*Ophiodon elongatus*)
J 24(8): 1833 (botulinum spore germination in fillet extracts)
(11): 2485 (fecundity re length–weight ratio)
CNG 82 (1966 Hecate Strait exploratory fishing catches)
CNS 28 (Canadian & U.S. trawl catches off B.C., 1954–65)
A 30 (enzymic degradation of muscle glycogen & adenosine phosphate, re quality)
32 (enzymic removal of muscle carbohydrates to inhibit flesh browning)
47 (description, habits, life history, fishery methods)

Linseed oil
S 1136 (storage of oxidizable fatty acid esters)

Lipase (*see* Enzymes)

Lipids (*see also* Acids, fatty; Liver oils; Oils and fats; Phospholipids; Tocopherol, α-)
J 24(3): 527 (hydrolysis in stored frozen Pac. dogfish)
(3): 607 (seasonal changes in flesh & liver, of Atlantic cod)
S 1175 (review of influence on frozen fish quality, particularly Atlantic cod)
A 69 (review of lipid hydrolysis & lipid–protein interaction re quality deterioration in frozen fish)

Lists of invertebrates (not separately indexed)
J 24(9): 1873 (collected in Hudson Bay)
(9): 1911 (parasites of freshwater Salmonidae & Coregonidae of insular Nfld.)
(12): 2515 (in starry flounder & sand sole stomachs)
S 1128 (in benthos of 4 Lake Superior bays)

Lists of fishes (*see also* common and scientific names of fishes)
J 24(10): 2101 (unusual species trawled off Queen Charlotte Is., B.C.)
(12): 2515 (in starry flounder & sand sole stomachs)
S 1128 (in benthos of 4 Lake Superior bays)

Lithology (*see* Geology)

Littorina littorea (*see* Periwinkle, common)

Liver; Liver oils
J 24(2): 357 (α-tocopherol content in fish & shellfish)
(3): 607, 613 (condition, lipid content, & lipid fatty acids seasonal changes in Atlantic cod)
(3): 613, 635 (structure details of oil fatty acids)
(8): 1701 (rainbow trout disturbance effects on)
S 1177, 1189 (fatty acids composition of Atlantic cod oil)
1186 (Atlantic cod depot fat triglyceride composition)

Lobster (*Homarus americanus*)
J 24(2): 221 (cooked meat preservation by gamma irradiation)
(2): 357 (α-tocopherol & lipids in flesh after unfed holding)
(6): 1403 (newly hatched larvae reaction to low salinity)
(11): 2339 (muscle weight re serum proteins, hepatopancreas, etc.)
(12): 2623 (combating *Gaffkya homari* infection)
B 147 (French edition of 1964 Bulletin on storage & shipment)

157 (economic appraisal of Canadian fishery)
CHN 31 (frozen storage of preheated whole)
S 1119, 1144 (hemolymph constituents)
1125 (triglyceride hydrolysis by lipase enzyme)
1186 (biosynthesis of depot fat from dietary triglycerides)
A 1 (Nfld. research review)
4(F) (handling; claw-fastening; shipping live)
5(F) (life history; Canadian & U.S. fishery production)
33 (good economic outlook for)
55 (same as CHN 31 above)
66 (feed studies)

Logperch (*Percina caprodes*)
J 24(5): 927 (limnetic larvae in N Wisconsin lakes)
S 1128 (in a Lake Superior bay)

Loring, Douglas Howard
S 1161 (rock salt bacteriological investigation)

Lota lota (*see* Burbot)

Lumbricinae (*see* Earthworms)

Luminescence (*see* Bioluminescence)

Lumpenus sagitta (see Prickleback, snake)

Lymnaea emarginata; *L. stagnalis* (*see* Snails, freshwater)

M

MacAskie, Ian Bruce
S 1115 (killer whale unusual group behaviour)

MacCallum, Wallace Allison
J 24(1): 127 (thawing processes effects on cod & redfish)
(3): 651 (postmortem changes in cod)
A 27 (Nfld. trap cod)

Mackenzie District, N.W.T.
B 158 (physical & economic organization of fisheries)
A 42 (fish freezer for Eskimos of Mackenzie River delta)

MacKenzie, William C.
B 157: ix (Foreword to Bulletin on Canadian lobster industry economics)
158: 1 (Foreword to Bulletin on organization of Mackenzie District, N.W.T., fisheries)

Mackerel, Atlantic (*Scomber scombrus*)
J 24(2): 357 (α-tocopherol & lipids in tissues of unfed held)
A 9(F) (description; life history; Canadian fishery)
43 (1965 Canadian ICNAF studies)

Mackerel, jack (*Trachurus symmetricus*)
J 24(10): 2201 (in line fishing from ocean weathership P)

MacLeod, John Cameron
J 24(6): 1241 (measuring fish swimming speed)

Macnab, Heather Claire
S 1131 (Atlantic salmon biosynthesis of 11-ketotestosterone and 11β-hydroxytestosterone)

MacPhail, John Stuart
S 1182 (clam hack fishing efficiency)

Magdalen Is., Gulf of St. Lawrence
S 1149 (herring fishery re sea temperatures)

Magnesium compounds
A 29 (changes in flesh of fish held in refrigerated sea water)

Maillard browning (*see* Browning of flesh)

Maine
J 24(7): 1553 (Penobscot River estuary hydrography)

Majak, W.
S 1110 (photosynthesis in green algae)

Malacostraca (*see Mysis relicta*)

Mallotus villosus (*see* Capelin)

Malpeque Bay, P.E.I.
J 24(2): 443 (serology of disease-resistant oyster stock)
S 1169 (common occurrence of *Thracia conradi*)

Management
B 157 (re economics & regulation of Canadian lobster fishery)
158 (re physical & economic organization of N.W.T. fisheries)
161: 39 (commercial goldeye fishery)
A 22, 36 (B.C. herring fishery)

Manefish (*Caristius macropus*)
J 24(10): 2101 (second record off B.C.)

Manitoba (*see also* names of localities and bodies of water)
J 24(5): 1017 (profundal benthic fauna of some lakes)
(6): 1407 (morphological comparison of lake trout with Ont. lakes populations)

Manitoulin Island (*see* South Bay, Ont.)

Mann, Cedric Robert
J 24(8): 1827 (aliasing on oceanic variability)

Mann, John Howard
J 24(7): 1613 (colour in grading canned salmon)

Mansfield, Arthur Walter
B 137 (artic and eastern Canada seals)
S 1188 (Canadian arctic waters harbour seal distribution)
1190 (Sable Is. mammals)

March, Beryl Elizabeth
J 24(6): 1291 (freshwater fish meals)

Margolis, Leo
J 24(4): 893 (*Triaenophorus crassus* in sockeye smolts)
S 1129 (N Pac. Ocean salmon)
1179 (*Caligus japonicus* Gussev)

Maria (*see* Burbot)

Marination; Marinated products (*see also* Salting)
A 6(F) (freshwater fish fillets)

Marion Lake, B.C.
J 24(11): 2283 (phytoplankton productivity factors)

Marking (*see also* Migration; Tagging)
J 24(4): 849 (salmon by antibiotic incorporation into bone)
(12): 2595 (vs. tagging effects on young Atlantic salmon survival and growth)

Martin, Nigel Vernon
J 24(5): 965 (lake trout pyloric caeca and gill-raker development)

Martin, William Robert
S 1148 (cod recruitment)

Mathematical treatment
J 24(2): 249 (Ricker model of equilibrium yield per recruitment)
(5): 1117 (of tests of migrating sockeye salmon fry stamina)
(5): 1155 (digitizing system for bathythermograph aperture cards)
(6): 1187 (sampling research trawl catches at sea)
(10): 2137 (pulp mill effluent concentration determination)
(11): 2355 (model of fish growth, respiration, & mortality)
(11): 2491 (computer vs. manual temperature & depth calculations)
(12): 2527 (exploitation of multiple stocks by a common fishery)

Mather, Frank Jewett, III
J 24(9): 1991 (transatlantic tuna migrations)

Mating (*see also* Reproduction)
J 24(3): 495 (non-interspecific of 2 sunfish species)
(9): 1955 (mate selection in mixed age-groups sockeye salmon population)

Matsumoto, Juichiro John
J 24(4): 873 (scallop muscle protein)

Matter, particulate, in natural waters (*see also* Productivity, primary)
J 24(5): 909 (continuous size spectrum, Saanich Inlet, B.C.)
S 1155 (Coulter electronic counter for)

Maturation; Maturity
J 24(1): 53 (definition of stages for Atlantic halibut)
(1): 67 (effect of feeding on thyroid, kidney, & pancreas of sexually ripening sockeye salmon)
(2): 243 (sexual, of sockeye salmon re starvation & flesh Na, K, & water content)
(6): 1209 (Nfld. bait squid)
(7): 1425 (brook trout)
(8): 1791 (sexual, of sockeye salmon re pituitary)
(12): 2573 (Atlantic cod in Ogac Lake, Baffin Is.)

May, Arthur William
J 24(2): 457 (blackberry in cod)
(7): 1531 (fecundity of Atlantic cod)

Mayflies
J 24(4): 769, 807, 823 (affected by N.B. forest insecticide sprays, re their role as salmon & trout feed)
S 1128 (in benthos of 4 Lake Superior bays)

McAllister, Donald Evan
J 24(3): 537 (significance of ventral bioluminescence)

McArn, Glynn
J 24(9): 2007 (neurofibroma in *Lumpenus sagitta*)

McBride, John Raymond
J 24(1): 67 (effects of feeding on salmon)
(2): 243 (flesh of salmon)
(8): 1791 (spawning sockeye pituitary)
S 1187 (rainbow trout hypophysectomy effects)

McBride, Roland Norman
J 24(3): 689 (experimental fishing shrimp pot)

McCart, Peter
J 24(1): 77 (hatchery release tank for salmon fry)
(2): 375 (sockeye salmon fry behaviour and ecology)
(2): 433 (scale regeneration in bluespot goby)

(9): 1999 (*Oncorhynchus nerka* gill rakers)

McCauley, James Elias
J 24(6): 1377 (status of *Brisaster latifrons*)
(6): 1385 (Echinoidea of Oregon)
(9): 1985 (hydroid epizoic on myctophid fishes)

McCleave, James David
J 24(10): 2011 (*S. clarki* homing and orientation)

McCombie, Alen Milne
J 24(1): 101 (thermal regime of South Bay, Ont.)

McCormick, Jon Michael
J 24(9): 1985 (hydroid epizoic on myctophid fishes)

McCracken, Francis Derwood
S 1147 (haddock distribution)

McCrimmon, Hugh Ross
J 24(1): 47 (young carp scale formation)

McFadden, James Thompson
J 24(7): 1425 (*Salvelinus fontinalis* numerical changes and population regulation)

McKenzie, Russel Alderson
J 24(1): 213 (fawn cusk-eel in NW Atl.)

McLachlan, Jack
S 1110 (photosynthesis in green algae)
1159 (dimethyl-β-propiothetin)
1183 (photosynthesis in algae)
A 40 (dimethyl-β-propiothetin)

McLaren, Ian Alexander
J 24(5): 975 (Ogac Lake biological studies)
(5): 981 (Ogac Lake physical and chemical characteristics)

McLeese, Donald Wilson
B 147(F) (lobster storage & shipment)

McMullen, John Clarence
J 24(12): 2627 (ocean, breeding of king crabs)

McNeil, William John
J 24(7): 1629 (randomness in pink salmon redds)

Meal, fish (see Fishmeal)

Meats
A 15 (nature of flavours in)

Medcof, John Carl
S 1182 (clam hack fishing efficiency)

Meganyctiphanes norvegica (a euphausid)
J 24(2): 467 (fatty acids composition vs. shrimp fatty acids)
S 1111 (lipids & fatty acids re effect on whale oil)

Megaptera novaeangliae (*see* Whale, humpback)

Melanogrammus aeglefinus (*see* Haddock)

Mercenaria mercenaria (*see* Quahaug)

Mercer, Malcolm Clarence
J 24(7): 1623 (*Zalophus californianus* in Nfld.)
(11): 2481 (wintering of pilot whales)
(12): 2631 (Atlantic walrus in Nfld.)

Meristic characteristics (*see also* Species, new; *also* Length; Size; Weight; etc.)
J 24(12): 2573 (Atlantic cod in Ogac Lake, Baffin Is.)
S 1129 (sockeye salmon re distribution & origins in N Pac. Ocean)
1156 (pink salmon re distribution & origins in N Pac. Ocean)

Merluccius bilinearis (*see* Hake, silver)

Merluccius productus (*see* Hake, Pacific)

Mesh size of nets (*see* Selectivity of fishing gear)

Metabolism
J 24(6): 1241 (swimming speed tests condition for increased active)
(6): 1253 (zebrafish oxygen uptake re zinc sulphate)
(8): 1701 (disturbance of rainbow trout effects on)
(8): 1731, 1775 (sockeye salmon re swimming performance)
(11): 2355 (re mathematical model for fish growth, respiration, & mortality)
S 1135 (of pyruvate & glyoxalate by Atlantic salmon & cod sperm)
1173 (of pyruvate in testes of rabbit & Atlantic cod)
1174 (of pyruvate in ovarian tissue of Atlantic cod)

Metazoa (*see* Zooplankton)

Micrococcus species
J 24(1): 9 (in fresh lake whitefish)

Micrometrus minimus (*see* Perch, dwarf)

Micropterus dolomieui (*see* Bass, smallmouth)

Micropterus salmoides (*see* Bass, largemouth)

Microstomus pacificus (*see* Sole, Dover)

Midges
J 24(4): 769, 807, 823 (affected by N.B. forest insecticide sprays, re their role as salmon & trout feed)

(5): 1017 (in profundal benthic fauna of some Man. lakes)

Migration (*see also* Behaviour; Distribution; Marking; Movements; Spawning; Tagging)
J 24(3): 569 (of British pink shrimp in a river)
(5): 1117 (of sockeye salmon fry re their stamina)
(8): 1743 (of Atl. brook trout re ponding)
(9): 1991 (transatlantic, of young bluefin tuna)
(10): 2011 (cutthroat trout olfaction & vision re homing)
(10): 2069 (sockeye salmon fry & smolts behaviour)
(11): 2321 (orientation in early sea migration of pink salmon)
(12): 2613 (genetic control in sockeye salmon fry lakeward)
(12): 2639 (Atlantic salmon Europe–Greenland via Irminger Sea)
B 157: 15 (lobster)
S 1129 (sockeye salmon in offshore N Pac. Ocean)
1133 (planted hatchery-reared trouts from Crecy Lake, N.B.)
1137 (salmons in N Pac. Ocean)
1150 (vertical, of Bay of Fundy re light)
1156 (pink salmon in offshore N Pac. Ocean)
1166 (orientation of young sockeye salmon during seaward)
A 19 (forecasting pink & sockeye salmon runs by high-seas tagging)
25 (recovery off Greenland of Canadian-tagged salmon)
56 (Atlantic salmon traced by tagging)

Miller, Bruce Stuart
J 24(12): 2515 (flatfish stomach contents)

Mills, Eric Leonard
J 24(2): 305 (biology of an ampeliscid pair)

Milt; Sperm (*see also* Testes)
J 24(3): 613 (seasonal lipids fatty acids changes in Atlantic cod)
(7): 1573 (fertility duration, in sockeye & pink salmon)
S 1135 (pyruvate & glyoxalate metabolism by Atlantic salmon & cod sperm)

Mineral content (*see also* Composition, chemical)
J 24(6): 1291 (of freshwater fish meals: 14 elements)

Minnow, bluntnose (*Pimephales notatus*)
S 1128 (in 2 Lake Superior bays)

Minnow, fathead (*Pimephales promelas*)
J 24(6): 1241 (maximum swimming speed & conditioning to increased metabolism)

Minnows
J 24(5): 927 (limnetic larvae in N Wisconsin lakes)

Minytrema melanops (*see* Sucker, spotted)

Miramichi River, N.B.
J 24(1): 21 (seasonal return pattern of Atlantic salmon)
(4): 701, 709, 731, 769, 807, 823 (effects of watershed forest insecticide sprays on salmon, trout, & aquatic insects)
S 1126 (Greenland salmon fishery influence on stocks & fishery of)
A 39 (life history & fishery, American smelt)

Mitchell, Edward
J 24(12): 2503 (Cuvier's beaked whale)

Model
J 24(11): 2473 (simple, of a lake, for instructional use)
B 156: 31 (hydraulic, of Dixon Entrance & Hecate Strait tides)

Model, mathematical (see Mathematical treatment)

Moisture content (*see* Composition; Drip; Water content)

Molds (*see* Moulds)

Mollusca (*see* subclassifications; *also* names of individual species, e.g. Clam, Mussel, Oyster, Scallop; Shipworms; Squid)

Molting (*see* Moulting)

Monochrysis lutheri
J 24(1): 201 (bacterial-toxin lecithinase C activity)

Monodon monoceros (*see* Narwhal)

Monogenea
J 24(10): 2161 (*Gyrodactylus* parasitic on surfperches)

Monostroma fuscum (an alga)
J 24(1): 33 (vertical distribution, Indian Arm, B.C.)

Morphology; Morphometry (*see also* names of organisms, organs, and tissues; *also* Anatomy; Histology)
J 24(3): 515 (of copepod *Phrixocephalus cincinnatus*)
(4): 887 (Great Lakes rainbow trout phenotypic characteristics)
(6): 1407 (3 populations of lake char compared)
(7): 1623 (California sea lion found off Nfld.)
(8): 1763 (new trematode species *Aporocotyle margolisi*)

(9): 1945 (new rockfish species *Sebastodes reedi*)
S 1129 (re sockeye salmon distribution in N Pac. Ocean)

Mortality (*see also* Disease; Insecticides; Predation)
J 24(1): 145 (fishing, re fishing effort for Arcto-Norwegian cod)
(4): 709, 731 (of Atlantic salmon & trout by insecticides)
(4): 843 (chinook salmon from fungus attack)
(7): 1627 (brook trout by an acanthocephalan invasion)
(10): 2117 (in a Lake Huron white sucker population)
(11): 2355, 2431 (mathematical model for fishes)
B 161: 21 (rates of goldeye)
S 1182 (in digging soft-shell clams)
1185 (haddock, ICNAF Subarea 3)
A 36 (Pacific herring spawn)

Mosquito (*Aedes aegypti*)
S 1146 (oxidase–peroxidase system in)

Moulds
S 1165 (*Saprolegnia* & *Achlya* on pink salmon eggs)

Moulting
J 24(2): 435 (of E Pac. harbour seal)
(6): 1229 (& respiration of euphausids)
(11): 2497 (insect moult-hormone activity of extract from Japanese yew branches)

Mounib, M. Said
S 1135 (metabolism by fish sperm)
1173 (pyruvate metabolism)
1174 (cod pyruvate metabolism)

Mount, Donald Irvin
J 24(2): 429 (lethal endrin in blood of gizzard shad)

Movements (*see* Behaviour; Marking; Migration; Tagging)

Moxostoma anisurum (*see* Redhorse, silver)

Moxostoma erythrurum (*see* Redhorse, golden)

Moxostoma macrolepidotum (*see* Redhorse, northern)

Moxostoma melanops (*see* Sucker, spotted)

Mudminnow, central (*Umbra limi*)
S 1128 (in a Lake Superior bay)

Mujib, Khwaja Abdul
J 24(6): 1315 (Gadidae cranial osteology)

Murai, Sueto
S 1156 (N Pac. pink salmon)

Musca domestica (*see* Fly, house)

Muscle (*see also* Fillets; Myogens; Protein; Quality)
J 24(2): 273 (choline derivatives in chilled rainbow trout)
(2): 357 (α-tocopherol & lipids content, fish & shellfish)
(3): 607, 613 (condition, lipid content, & lipid fatty acids seasonal changes in Atlantic cod)
(3): 651 (postmortem physicochemical changes in unfrozen Atlantic cod)
(4): 873 (protein in extracts of scallop)
(8): 1701 (rainbow trout disturbance effects on adrenaline & catecholamine in skeletal)
(8): 1717 (adenosine monophosphate aminohydrolase in Atlantic cod prerigor & postrigor)
(8): 1837 (nucleotide degradation re postmortem changes in relaxed Atlantic cod)
(9): 1945 (protein electropherograms of *Sebastodes* species)
(11): 2229 (hypoxanthine formation in iced yellow walleye)
(11): 2339 (weight in lobster re serum proteins, hemocytes, & hepatopancreas)
(12): 2549 (ultrastructure of Atlantic cod white striated myotomal)
(12): 2555 (phospholipase A activity in rainbow trout)
B 160 (changes in salt content, nitrogenous constituents, etc. in fish held in refrigerated sea water)
S 1117, 1124 (review of postmortem changes in sugars, sugar phosphates, etc. in fish)
A 29 (changes in fish passing through rigor while held in refrigerated sea water)
30 (glycogen & adenosine phosphate degradation in fish)
32 (enzymic removal of carbohydrate in, re inhibition of browning)
69 (review of chemical changes in frozen, re organoleptic quality)

Mussel, bay (Atlantic) (*Mytilus edulis*) (blue mussel)
J 24(2): 357 (α-tocopherol & lipids in unfed held)

Mussel, blue (*see* Mussel, bay (Atlantic))

Mussel, horse (*Volsella modiolus*)
J 24(2): 357 (α-tocopherol & lipids in unfed held)

Mussel, ribbed (*Volsella demissa*)
J 24(2): 357 (α-tocopherol & lipids in unfed held)

Mussels, freshwater
J 24(3): 679 (tumor-like growth on foot of *Anodonta californiensis*)

(5): 1165 (shell-weight re age of *Anodonta anata* in British waters)

Mya arenaria (*see* Clam, soft-shell)

Myctophum nitidulum (*see* Lanternfishes)

Myogens (*see also* Muscle)
J 24(2): 299 (of Catostomidae re speciation)
(6): 1269 (electropherograms of lampreys muscle)
(7): 1607 (amino acids of trout muscle)

Myoxocephalus quadricornis (*see* Sculpin, fourhorn)

Mysidacea (*see also* subclassifications)
J 24(5): 1101 (*Gnathophausia gracilis* fatty acids composition)

Mysis relicta (a malacostracan)
J 24(2): 463 (introduction into 2 B.C. lakes as trout feed)
S 1128 (in benthos of 4 Lake Superior bays)
A 14 (Great Bear Lake, N.W.T.)

Mytilus edulis (*see* Mussel, bay (Atlantic))

Myxophyceae
S 1113 (extracts as bactericides)

N

Nakano, Tomoo
J 24(8): 1701 (trout catecholamine and carbohydrate concentrations)

Nakatani, Roy Eiji
J 24(4): 867 ("gas-bubble" disease in salmon)

Nansenia candida (an argentinid fish)
J 24(10): 2101 (second record off B.C.)

Narver, David Wells
J 24(10): 2045 (Babine Lake primary productivity)
(10): 2189 (primary production in 2 B.C. lakes)

Narwhal (*Monodon monoceros*)
A 75 (Canadian Arctic studies, 1965)

Nassarius obsoletus (*see* Snail, mud)

Navicula grevillei
J 24(1): 33 (vertical distribution, Indian Arm, B.C.)

Neal, Wanda Eloise
J 24(2): 221 (radiation on storage of cooked lobster)

Nealotus tripes (a gempylid fish)
J 24(5): 1177 (new to Canadian Atl.)

Neave, Ferris
S 1156 (N Pac. pink salmon)

Needler, George Treglohan
J 24(8): 1827 (aliasing on oceanic variability)

Nematoda
J 24(3): 629 (*Anisakis* infestation as indicator of surf smelt populations heterogeneity)
(9): 1911 (descriptions; parasitic on Nfld. freshwater fishes)
(10): 2161 (*Anisakis* & *Cucullanus* parasitic on surfperches)

Nervous system
S 1181 (Cerantharia nervous system responses)

Net, gill
B 161: 35, 39 (for goldeye commercial fishing)

Nets (*see also* Gear; Fishing methods; Trawl)
J 24(4): 709, 731, 769, 823 (for determining effects of forest insecticide sprays on Atlantic salmon, trout, & aquatic insects)

New Brunswick (*see also* Miramichi River)
J 24(4): 701, 709, 731, 769, 807, 823 (effect of spraying forests with insecticides on salmon, trout, & aquatic insects)
(11): 2241 (bedrock & sediments of Kouchibouguac Bay)
B 157 (lobster industry economic appraisal)
CHN 29 (capacities of fishmeal plants)

Newfoundland
J 24(5): 1077 (age & growth of American plaice in waters near)
(6): 1209 (growth & hypothetical age of bait squid)
(7): 1531 (cod fecundity)
(7): 1623 (record of California sea lion)
(9): 1911 (description of 26 species of parasites from freshwater Salmonidae & Coregonidae)
(11): 2481 (pilot whales wintering in inshore waters)
(12): 2631 (Atl. walrus records)
B 157 (lobster industry economic appraisal)
CHN 29 (capacities of fishmeal plants)
A 1 (research on commercial marine invertebrates)

Nitrate
J 24(5): 899 (in subarctic Pac. Ocean)
(5): 981 (in Ogac Lake semi-marine waters)

Nitrite
J 24(5): 899 (in Ogac Lake semi-marine waters)
CVG 37 (for preserving herring aboard vessel before reduction)

Nitrogen content (*see also* Composition, chemical)

J 24(5): 909 (of Saanich Inlet, B.C., particulate matter)

Noctiluca (dinoflagellates)
J 24(8): 1811 (recoveries by two plankton sampling methods)

Nomenclature
J 24(5): 1067 (lampreys)
S 1164, 1179 (confusion in copepod *Caligus* species)

Northumberland Strait
J 24(11): 2241 (bedrock & sediments structure off NW end)

Northwest Territories, Canadian
B 158 (physical & economic organization of Mackenzie District fisheries)

Notolepis rissoi rissoi (*see* Barracuda, ribbon)

Notropis atherinoides (*see* Shiner, emerald)

Notropis cornutus (*see* Shiner, common)

Notropis deliciosus (*see* Shiners)

Notropis hudsonius (*see* Shiner, spottail)

Nova Scotia (*see also* Sable Island; *also* names of specific localities)
B 157 (lobster industry economic appraisal)
CHN 29 (capacities of fishmeal plants)

Nowlan, Sandra Claire
J 24(8): 1837 (postmortem cod muscle)

Nucleosides; Nucleotides (see *also* Acids, nucleic)
J 24(8): 1837 (degradation re changes in postmortem Atlantic cod muscle)
S 1112 (C^{14}-traced formation by salmon & trout testes tissue)
1117 (review of postmortem changes in fish muscles)
A 38 (review of, in fish)

Nutrition value (*see also* Composition, chemical; Vitamin B group)
J 24(6): 1291 (freshwater fishmeals)

O

Obituary
J 24(9): 1979 (Edgar Clark Black)

Ocean (*see* name of ocean, *also* Oceanography)

Oceanography, arctic
J 24(5): 975, 981 (Ogac Lake, Baffin Is.)
S 1127 (Labrador Sea, Davis Strait, S Baffin Bay)
A 52 (general)

Oceanography, B.C. coast (*see also* Georgia, Strait of; Inlets; Oceanography, N Pac. Ocean)
J 24(1): 33 (Indian Arm, re algae vertical distribution)
(11): 2207 (oceanic-coastal waters annual changes)
B 156 (physical, of Dixon Entrance, Hecate Strait, etc.)
A 52 (general)

Oceanography, Canadian Atl. coast (*see also* Hydrography)
J 24(7): 1553 (Penobscot R. estuary, Maine)
(9): 1845 (bottom residual drift on Continental Shelf area)
S 1142, 1143 (long-term variations in Scotian Shelf area waters)
1147 (re haddock distribution)
1148 (re cod recruitment)
1149 (re Magdalen Is. herring fishery)
A 43 (Canadian 1965 ICNAF researches in Subareas 1–5)
52 (general)

Oceanography, general (*see also* Hydrography)
J 24(5): 1155 (digitizing system for bathythermograph aperture cards)
(8): 1827 (aliasing effect on long-term oceanic variability studies off Canada's coasts)
(11): 2491 (computer vs. manual temperature & depth calculations)
S 1120 (tracing coastal currents by aerial photography)
1162 (measuring sodium sulphate activity coefficient)
A 52 (Water, the Producer—Weather of the Sea)

Oceanography, N Pac. Ocean
J 24(5): 899 (chemical features of subarctic boundary)
(11): 2207 (oceanic-coastal waters annual changes)
CNG 79 (recent groundfish fishery developments)
S 1137 (re salmons distribution)
A 52 (general)
60 (same as CNG 79 above)

Oceanography, SE Alaska
J 24(7): 1475 (larger inlets)

Odense, Paul Holger
J 24(3): 651 (posmortem changes in cod)
(12): 2549 (cod myotomal muscle)
S 1119 (*Homarus americanus* hemolymph constituents)

Odobenus rosmarus rosmarus (*see* Walrus, Atlantic)

Odonata (*see* Dragonflies)

Odours (*see also* Quality of fish products)
J 24(2): 457 (marine phytoplankton thetin as precursor of dimethyl sulphide odour in Atlantic cod flesh)

B 160 (in salmon held in refrigerated sea water)

Odours, reaction to
J 24(10): 2011 (re cutthroat trout homing & orientation)

Ogac Lake, Baffin Is.
J 24(5): 975, 981 (history of biological studies; hydrography and chemistry of its semi-marine waters)
(12): 2573 (Atlantic cod biology in; bathymetry)

Oils and fats, aquatic animals (*see also* Acids, fatty; Liver oils; Lipases)
J 24(3): 365 (gray seal blubber)
(6): 1203 (binding of, in canned sockeye salmon)
(6): 1209 (of sheepshead, tullibee, burbot, & alewife: yield & composition from reduction)
S 1111 (fin whale blubber)
1118 (polar bear & Atlantic harbour seal blubber)
1170 (corn oil triglycerides)

Olfactory perception and response (*see* Odours, reaction to)

Oncorhynchus gorbuscha (*see* Salmon, pink)

Oncorhynchus keta (*see* Salmon, chum)

Oncorhynchus kisutch (*see* Salmon, coho)

Oncorhynchus nerka (*see* Salmon, sockeye; *also* Kokanee)

Oncorhynchus tshawytscha (*see* Salmon, chinook)

Oneirodes acanthias (an anglerfish)
J 24(10): 2101 (first record off B.C.)

Oneirodes eschrichti-group (anglerfishes)
J 24(10): 2101 (second record off B.C.)

Ontario (*see also* names of localities and bodies of water)
J 24(6): 1407 (morphological comparison of lake trout with Man. lakes populations)

Ontario, Lake
J 24(4): 887 (rainbow trout phenotypic characteristics)

Opeongo, Lake, Ont.
J 24(1): 87 (smallmouth bass growth re temperature)

Ophiodon elongatus (*see* Lingcod)

Ophiuroids (*see* Starfishes, brittlestar)

Orcinus rectipinna (*see* Whale, killer)

Orconectes (*see* Crayfish)

Oregon
J 24(5): 917 (steelhead trout fecundity in Alsea River)
(6): 1385 (Echinoidea)

Organolepsis (*see* Light, reactions to; Odours, reactions to; Quality; Salinity, reactions to; Sound, reactions to)

Organoleptic tests (*see* Quality of fishery products)

Orientation
J 24(10): 2011 (re cutthroat trout homing)
(11): 2321 (during pink salmon early marine migration)
S 1166 (young sockeye during migration from lakes)

Osmerus mordax (*see* Smelt, American)

Osmoregulation (*see* Acclimation; Salinity, reactions to)

Osteology
J 24(6): 1315 (of Gadidae crania)
S 1188 (of jaw re *Phoca vitulina* subspecies)

Ostovar, Kurosh
J 24(1): 9 (whitefish preservation with radiation)

Ostrea edulis (*see* Oyster, European)

Otoliths
J 24(5): 1077 (in American plaice age determinations)
(12): 2573 (in Ogac Lake Atlantic cod age determinations)

Outram, Donald Noel
CNG 77 (herring spawn abundance in B.C.)
83 (B.C. herring spawn, 1967)
A 36 (Pacific herring)
59 (herring spawn abundance)
62 (herring spawn abundance in B.C.)

Ova (*see* Eggs)

Ovary (*see also* Eggs)
S 1174 (pyruvate metabolism by Atlantic cod tissue)

Overbeeke, A. P. van
J 24(8): 1791 (spawning sockeye pituitary)

Oxygen, dissolved (*see also* Limnology; Oceanography)
J 24(3): 475 (influence on juvenile largemouth bass growth)
(6): 1253 (uptake of zebrafish re resistance to zinc sulphate)
(6): 1299 (absence in guanotrophic region of a small lake)
(11): 2355, 2395, 2398, 2400, 2402 (consumption of various fishes, mathematically treated)

Oyster, Atlantic (*Crassostrea virginica*)
J 24(2): 357 (α-tocopherol & lipids in unfed held)
(2): 443 (serological differences between two populations)
(6): 1413 (freeze-drying for total solids assay re condition)
(10): 2155 (chromosomes)
CSG 51 (progress in Canadian hatchery development)
S 1122 (experimental chemical control of eelgrass on beds)
1134 (hatchery procedure development)
A 35 (stocks rehabilitation)

Oyster, European (*Ostrea edulis*)
J 24(5): 1165 (shell-weight re age in British waters)

Oyster, Pacific (*Crassostrea gigas*)
J 24(4): 883 (sampler for planktonic larvae)
(8): 1833 (botulinum spore germination in tissue extracts)
(10): 2155 (chromosomes)

Ozonolysis
S 1151 (esterification of fatty acids ozonides products)

P

Pachycerianthus (a ceriantharian)
S 1181 (nervous system responses & histology)

Pacific Ocean, NE (*see also* Oceanography)
CNG 79 (recent developments in groundfish trawl fishery)
A 19 (predicting pink & sockeye salmon runs by high-seas tagging)
60 (same as CNG 79 above)

Pacific Ocean, N (*see also* Oceanography; Weathership Station P)
J 24(3): 581 (Ekman transport re zooplankton concentration off California & in Bering Sea)
(5): 899 (chemical features of subarctic boundary)
S 1129 (distribution of sockeye salmon in offshore)
1137 (longline fishing, tagging, & racial studies of salmons)
1156 (distribution of pink salmon in offshore)

Pagophilus groenlandicus (*see* Seal, harp)

Palaemonetes pugio (a decapod)
J 24(11): 2467 (measuring feed retained by)

Paloheimo, Jyri Erkki
S 1158 (groundfish heterogeneity)

Pancreas
J 24(1): 67 (effect of feeding on, in sexually ripening sockeye salmon)
(11): 2339 (lobster hepatopancreas re muscle weight, etc.)

Pandalopsis dispar (*see* Shrimp, sidestripe)

Pandalus (various species) (*see* Prawn; Shrimps)

Pandalus borealis (*see* Shrimp, pink (Canada))

Pandalus danae (*see* Shrimp, coonstripe)

Pandalus hypsinotus (*see* Shrimp, humpback)

Pandalus jordani (*see* Shrimp, smooth pink)

Pandalus montagui (*see* Shrimp, pink (England))

Pandalus platyceros (*see* Prawn)

Panope generosa (*see* Geoduck)

Paralithodes camtschatica (*see* Crab, king)

Paranjape, Madhu A.
J 24(6): 1229 (euphausid molting and respiration)

Parapronoe crustulum (a pelagic amphipod)
J 24(3): 687 (bioluminescence)

Parasites; Parasitism (*see also* Disease)
J 24(3): 629 (*Anisakis* nematodes in surf smelt)
(4): 893 (*Triaenophorus* in sockeye salmon smolts)
(6): 1275 (*Sphyrion* on & in pelagic redfish re redfish populations)
(7): 1627 (*Echinorhynchus lateralis* in brook trout)
(9): 1911 (description of 26 species from freshwater Salmonidae & Coregonidae of insular Nfld.)
(9): 1985 (*Hydrichthys* epizoic on myctophid fishes & on their parasitic copepods)
(10): 2161 (re host fishes specificity)
(12): 2539 (sea lamprey on Georgian Bay rainbow trout)
B 161: 33 (of goldeye)
S 1129 (re sockeye salmon distribution in N Pac. Ocean)
1156 (re pink salmon distribution in N Pac. Ocean)

Park, Kilho
J 24(5): 899 (subarctic boundary chemical features)

Park, Tai Soo
J 24(2): 231 (2 new species of copepods from the Strait of Georgia)

Parker, Robert Ray
S 1179 (*Caligus japonicus* Gussev)

Parkinson, John Perry
S 1134 (Canadian oyster hatchery development)

CSG 51 (Canadian oyster hatchery development)

Parophrys vetulus (*see* Sole, lemon (Pacific))

Parsons, John Wilson
J 24(5): 1035 (blue pike contributions to Lake Erie fishery)

Parsons, Timothy Richard
J 24(5): 909 (size spectrum for particle size in the sea)
S 1155 (Coulter Counter)
1172 (phytoplankton blooms)

Particulate matter (*see* Matter, particulate)

Pasiphaea (a deepsea decapod)
J 24(5): 1101 (fatty acids composition)

Pasteurization (*see* Irradiation)

Pathological conditions (*see* Disease)

Patriquin, David G.
J 24(12): 2573 (Ogac Lake *Gadus morhua*)

Paulik, Gerald John
J 24(2): 249 (computer program for yield per recruitment)
(12): 2527 (stock exploitation)

Pauley, Gilbert Buckhannan
J 24(3): 679 (tumor-like growth on the foot of a freshwater mussel)
(4): 843 (adult salmon mortality due to *Dermocystidium*)
(4): 867 ("gas-bubble" disease in salmon)

Pecten maximus (*see* scallop)

Peden, Alex Edward
J 24(1): 1 (North Pacific prickleback; correction on, J 24(12): 2641)
(12): 2641 (*Alectridium aurantiacum*: correct spelling)

Pelage (*see also* Pelts)
J 24(2): 435 (moult re follicle anatomy in E Pac. harbour seal)
(2): 451 (patterns re population distribution, E Pac. harbour seal)
CHN 28 (care & treatment of Atlantic seal)

Pelecypoda (*see also* subclassifications)
S 1128 (in benthos of 4 Lake Superior bays)

Pelts (*see also* Pelage)
CHN 28 (care & treatment of Atlantic seal)

Pennell, James Thomas
S 1146 (insect oxidase–peroxidase system)

Penobscot River, Maine
J 24(7): 1553 (estuary hydrography & biology)

Perca flavescens (*see* Perch, yellow)

Perch, black (*Embiotoca jacksoni*)
J 24(10): 2161 (parasitization re other surfperches)

Perch, dwarf (*Micrometrus minimus*)
J 24(10): 2161 (parasitization re other surfperches)

Perch, kelp (*Brachyisteus frenatus*)
J 24(10): 2161 (parasitization re other surfperches)

Perch, ocean (Pacific) (*Sebastodes alutus*)
J 24(6): 1187 (re sampling research trawl catches at sea)
(9): 1945 (hemoglobin & muscle protein electropherograms)
CNG 79 (Japanese catches in N Pac., 1963–66)
82 (1966 Hecate Strait exploratory fishing catches)
CNS 28 (Canadian & U.S. trawl catches off B.C., 1954–65)
A 37 (B.C. & U.S. landings, 1956–63, & fisheries potential)
60 (same as CNG 79 above)

Perch, pile (*Rhacochilus vacca*)
J 24(10): 2161 (parasitization re other surfperches)

Perch, shiner (*Cymatogaster aggregata*)
J 24(10): 2161 (parasitization re other surfperches)

Perch, yellow (*Perca flavescens*)
J 24(3): 695 (blood low-mobility proteins)
(5): 927 (limnetic larvae in N Wisconsin lakes)
S 1128 (in a Lake Superior bay)

Percina caprodes (*see* Logperch)

Percopsis omiscomaycus (see Trout-perch)

Periwinkle, common (*Littorina littorea*)
J 24(2): 357 (α-tocopherol & lipids in unfed held)

Petromyzon (genera only)
J 24(5): 1067 (in lampreys key)

Petromyzon marinus (*see* Lamprey, sea)

Petromyzontidae (*see* Lampreys)

Pettibone, Marian Hope
S 1123 (type-specimens of polychaetes)

*p*H (*see also* Alkalinity; Limnology; Oceanography)
J 24(3): 651 (of muscle in unfrozen Atlantic cod)

Phanerodon furcatus (*see* Seaperch, white)

Phenotypic characteristics (*see* Morphology)

Phinney, Duane Earl
J 24(1): 209 (fin pigmentation to distinguish Alaska chinook and coho)

Phoca vitulina concolor (*see* Seal, harbour (W Atl.))

Phoca vitulina mellonae (*see* Seal, Ungava freshwater)

Phoca vitulina richardi (*see* Seal, harbour (E Pac.))

Phocaena phocaena (*see* Porpoise, common)

Phosphamidon (*see* Insecticides)

Phosphates
J 24(5): 899 (in subarctic Pac. Ocean)
S 1117, 1124 (review of sugar, in postmortem changes in fish muscles)
A 12(F), 65 (polyphosphate dips retard water loss during fillet processing)
30, 32 (sugar, re enzymic degradation in fish flesh to inhibit browning)
38 (review of, in fish)

Phospholipase (*see* Enzymes)

Phospholipids
J 24(2): 273 (glycerylphosphorylcholine in chilled trout muscle)
(3): 607, 613 (seasonal changes in Atlantic cod flesh, liver, roe, & milt lipids)
(12): 2555 (phospholipase A activity in rainbow trout muscle)
S 1175 (influence on fish quality, particularly Atlantic cod)
1178 (choline utilization in aerobic marine microbe synthesis of)
1189 (of 4 freshwater vs. 2 marine fish oils fatty acids)
A 38 (review of, in fish)

Photography
B 159 (automatic underwater, for fisheries research)
S 1120 (aerial, for tracing coastal currents re pollution)
A 61(F) (underwater, for tracing fish movements into nets or trawls)

Photosynthesis (*see also* Algae; Phytoplankton; Plankton; Productivity, primary; Thetin derivatives)
S 1110, 1159, 1183 (in Chlorophyceae & Prasinophyceae algae)

Phrixocephalus cincinnatus (a copepod)
J 24(3): 515 (morphology)

Phylogeny
J 24(10): 2161 (of host fishes re parasites)

Physa (*see* Snails, freshwater)

Physeter catodon (*see* Whale, sperm)

Phytoplankton (*see also* Algae; Diatoms; Feed; Plankton; Productivity, primary)
J 24(1): 201 (examination of marine, for lecithinase C)
(2): 457 (thetin content as precursor of dimethyl sulphide odour in Labrador cod flesh)
(9): 1861 (dynamics in Alaskan arctic lake)
(11): 2283 (spatial & temporal differences in productivity in a lake)
S 1155 (Coulter electronic counter for quantitative estimation)
1172 (dependence of zooplankton grazing on size of)
1191 (some of marine origin in 291 Great Bear Lake species)

Pickard, George Lawson
J 24(7): 1475 (oceanographic characteristics of SE Alaska inlets)
(11): 2207 (E subarctic Pac. waters changes)

Pickerel, grass (*Esox americanus vermiculatus*)
J 24(3): 695 (blood low-mobility proteins)

Pickerel, yellow (*see* Walleye)

Pigments; Pigmentation
J 24(1): 209 (of fins for distinguishing juvenile chinook from coho salmon)
(2): 451 (pelage patterns of E Pac. harbour seal)
(3): 527 (of stored frozen Pac. dogfish re flesh quality)
(7): 1613 (of canned Pac. salmons re grading)
(10): 2195 (xanthophylls in unusual, of sockeye salmon skin)
CHN 30 (discolored flesh problem in gillnetted Greenland halibut)
S 1145 (optical activity of seaweed fucoxanthin)

Pike, blue (*Stizostedion vitreum glaucum*)
J 24(5): 1035 (contributions of year-classes to Lake Erie commercial fishery)

Pike, northern (*Esox lucius*)
J 24(3): 695 (blood low-mobility proteins)
B 158 (in economics of N.W.T. commercial fisheries)
A 6(F) (marinated fillets & similar products)
14 (Great Bear Lake, N.W.T.)

Pilchard (*Sardinops sagax*) (Pacific sardine)
A 70, 72(F) (brief description)

Pimephales notatus (*see* Minnow, bluntnose)

Pimephales promelas (*see* Minnow, fathead)

Pinaus Lake, B.C.
J 24(2): 463 (introduction *of Mysis relicta* as trout feed)

Pippy, John Herbert Charles
J 24(7): 1627 (kill of *Salvelinus fontinalis* involving *Echinorhynchus lateralis*)
(9): 1911 (Nfld. freshwater fish parasites)
A 58 ("swimmer's itch")

Pitt, Thomas Kenton
J 24(5): 1077 (American plaice age and growth)

Pituitary
J 24(8): 1791 (of sockeye salmon during sexual maturity & spawning)
(8): 1823 (hormone action on hypophysectomized American eel)
S 1187 (effect of hypophysectomy on rainbow trout pituitary–interrenal axis)

Placopecten magellanicus (*see* Scallop, giant)

Plaice (European) (*Pleuronectes platessa*)
J 24(11): 2407 (mathematical treatment of growth & feeding)

Plaice, American (*Hippoglossoides platessoides*) (blackback flounder)
J 24(5): 1077 (age & growth in Nfld. area)
A 43 (Nfld. landings in 1964)

Plankton (*see also* Feed; Phytoplankton; Zooplankton)
J 24(4): 883 (sampling device)
(8): 1811 (pumping device for sampling small marine)
A 52 (in oceans, general)

Plasma (*see* Blood)

Platford, Robert Frederick
S 1162 (sodium sulfate in sea water)

Platichthys stellatus (*see* Flounder, starry)

Plecoptera (*see* Stoneflies)

Pleuroncodes planipes (a benthic decapod)
J 24(5): 1101 (fatty acids composition)

Pleuronectes platessa (*see* Plaice (European))

Polistotrema deani (*see* Hagfish, black)

Pollachius virens (*see* Pollock)

Pollock (*Pollachius virens*)
A 43 (1965 landings in Canadian ICNAF Subarea 4)

Pollock, walleye (*Theragra chalcogrammus*)
CNG 79 (Japanese catches in N Pac., 1963–66)
A 60 (same as above)

Pollution (*see also* Insecticides)
J 24(2): 429 (endrin detection in gizzard shad blood)
(6): 1253 (zebrafish age re resistance to zinc sulphate)
(10): 2137 (kraft mill effluent distribution in a B.C. harbour)
S 1120 (tracing coastal by aerial photography)
1157 (apparatus for measuring hydrogen sulphide oxidation kinetics)
A 52 (sewage disposal in sea)

Polychaeta
S 1123 (type-specimens described by Edith & Cyril Berkeley, 1923–64)
1138 (new B.C records & range extensions)

Pomfret (*Brama raii*)
J 24(10): 2201 (preponderate in line catches from ocean weathership P)

Pomoxis nigromaculatus (*see* Crappie, black)

Ponding
J 24(8): 1743 (brook trout)
A 57(F) (brook, brown, & rainbow trout)

Populations (*see also* Stocks)
J 24(1): 145 (dynamics of Arcto-Norwegian Atlantic cod)
(2): 443 (serological differences of Atl. oysters)
(2): 451 (re pelage patterns of E Pac. harbour seal)
(3): 629 (heterogeneity of surf smelt, judged by *Anisakis* infestation)
(6): 1275 (redfish in Labrador Sea)
(6): 1407 (morphology of lake char compared)
(7): 1425 (brook trout regulation & numerical changes)
(9): 1955 (mate selection in mixed age-groups of sockeye salmon)
(10): 2117 (sea lamprey effects on a Lake Huron white sucker)
(12): 2573 (estimates of Atlantic cod in Ogac Lake, Baffin Is.)
CAG 9 (NW Atl. large whale species, particularly fin whale)
A 36 (distribution, of B.C. herring)
75 (Greenland cod, seals, & whales in Canadian Arctic)

Porbeagle (*Lamna nasus*)
A 43 (1965 landings in Canadian ICNAF area)

Porphyridium cruentum (a unicellular red alga)
S 1159 (photosynthetic thetin in)
1171 (aldolase activity in)
A 40 (same as S 1159 above)

Porpoise, common (*Phocaena phocaena*)
S 1190 (on Sable Is., N.S.)

Potassium compounds
J 24(2): 243 (in sockeye salmon flesh re sexual maturity & starvation)
A 29 (changes in flesh of fish held in refrigerated sea water)

Poultry
A 15 (nature of flesh flavours)

Powell, Neil Andrew
J 24(9): 1905 (*Cribrilina annulata* sexual dwarfism)
(9): 2003 (*Figularia quaylei*: a new bryozoan)

Power, Henry Edwin
J 24(2): 221 (radiation on storage of cooked lobster)
(7): 1521 (isopropyl alcohol in fish protein)

Powles, Percival Mount
J 24(1): 207 (Atlantic wolffish eggs off N.S.)

Prakash, Anand
J 24(7): 1589 (*Gonyaulax tamarensis* growth and toxicity)

Prasinophyceae
S 1110, 1189 (photosynthesis products in various species)

Prawn (*Pandalus platyceros*) (spot shrimp) (*see also* Shrimp)
J 24(3): 687 (trap for experimental fishing, Alaska)
CNG 76 (exploration in Hecate Strait & Queen Charlotte Sound, B.C. 1966)
A 50 (description)

Precipitation (*see* Dilution effect)

Predation (*see also* Feed)
J 24(1): 215 (of large amphipod on skate)
(2): 375 (of fish & birds on Babine R. sockeye salmon fry)
(5): 1117 (sockeye salmon migrant fry vulnerability to, as stamina test)
(10): 2069 (on Alaskan migrating sockeye salmon fry & smolts)
(10): 2117 (sea lamprey on Lake Huron white suckers)
B 161: 33 (on goldeye)
CNG 80 (dogfish on B.C. herring)
S 1132 (on Atlantic salmon & trouts by various birds)
A 36 (on & by Pacific herring

Prediction (*see* Forecast)

Preservatives and preservative treatments (*see also* Antibiotics; Antioxidants; Freezing; Irradiation; Rancidity; Refrigeration)
J 24(4): 895 (isopropyl alcohol for fish protein concentrate raw materials)
(5): 1179 (acetylated monoglycerides as bacteriostatic dips for frozen Atlantic cod)
CVG 37 (B.C. summer herring on vessel prior to reduction)

Prickleback, North Pacific (*Alectridium aurantiacum*)
J 24(1): 1 (redescription of Alaska species; distinction from similar species & genera; correction on, J 24(12): 2641)

Prickleback, snake (*Lumpenus sagitta*)
J 24(9): 2007 (neurofibroma on snout)

Prince Edward Island (*see also* Ellerslie; Malpeque Bay)
B 157 (lobster industry economic appraisal)
CHN 29 (capacities of fishmeal plants)

Prionace glauca (*see* Shark, blue)

Productivity, primary
J 24(5): 909 (in Saanich Inlet, B.C., particulate matter)
(9): 1861 (phytoplankton dynamics in Alaskan arctic lake)
(10): 2045, 2189 (carbon production in Babine Lake system, B.C.)
(11): 2283 (phytoplankton temporal & spatial, Marion Lake, B.C.)
A 52 (of the sea)

Prolactin, ovine (*see* Hormones)

Prosopium cylindraceum (*see* Whitefish, round)

Prospecting (*see* Exploration)

Protein (*see also* Amino acids; Electropherograms; Muscle; Proteolysis)
J 24(3): 527 (denaturation in stored frozen Pac. dogfish)
(3): 695 (distribution of low mobility, in freshwater fishes blood)
(4): 873 (in scallop striated muscle extracts)
(11): 2339 (of lobster serum re muscle weight, etc.)
S 1119, 1144 (constituents of lobster hemolymph)

Protein concentrate ("fish flour")
J 24(4): 895 (preservation of Atlantic cod scrap as raw material for; analysis of product)
(7): 1521 (residual isopropyl alcohol determination)

Proteolysis
B 160 (in flesh of fish held in refrigerated sea water)

Protothaca staminea (*see* Clam, little-neck)

Protozoa (*see* Zooplankton)

Psettichthys melanostictus (*see* Sole, sand)

Pseudoalectrias species
J 24(1): (distinction from *Alectridium* species)

Pseudocalanus
J 24(3): 555 (in Tanquary Fjord, Ellersmere Is., zooplankton)

Pseudomonas species
J 24(1): 9 (in fresh lake whitefish)
A 32 (*P. fragi* enzyme for removal of fish muscle carbohydrates to inhibit flesh browning)

Pseudopleuronectes americanus (*see* Flounder, winter)

Pteropoda
J 24(2): 457 (*Limacina helicina* in feed cause of blackberry flesh condition of Labrador cod)

Publications and Reports, Fisheries Research Board of Canada
J 24(12) (list of 1967 and some 1966)

Puget Sound, Washington
J 24(12): 2515 (starry flounder & sand sole stomach contents)

Pulp mill effluents (*see* Pollution)

Pumpkinseed (*Lepomis gibbosus*) (pumpkinseed sunfish)
J 24(3): 495 (reproductive isolation from bluegill)
(3): 695 blood low-mobility proteins)
(5): 927 (limnetic larvae in N Wisconsin lakes)

Pumps
A 34 (for unloading fish from vessels)

Pungitius pungitius (*see* Stickleback, ninespine)

Purines; Pyrimidines
J 24(5): 955 (in integument of Atlantic salmon during parr–smolt transformation)
(11): 2229 (hypoxanthine formation in iced freshwater fish muscle)
S 1112 (traced incorporation into nucleic acid derivatives by salmon testes tissue)

Pycha, Richard Lawrence
J 24(2): 281 (hatchery-reared trout returns)

Pyrimidines (*see* Purines)

Pyruvate
S 1135 (metabolism by Atlantic salmon & cod sperm)
1173 (metabolism by rabbit & Atlantic cod testes)
1174 (metabolism by Atlantic cod ovarian tissue)

Q

Qadri, Sami Ullah
J 24(6): 1407 (morphological comparisons of *Cristovomer namaycush*)

Quahaug [quahog], bay (*Venus mercenaria*) (*Mercenaria mercenaria*)
J 24(2): 357 (α-tocopherol & lipids in unfed held)
(5): 1165 (shell-weight re age, in British waters)

Quahaug [quahog], ocean (*Artica islandica*)
J 24(2): 357 (α-tocopherol & lipids in unfed held)

Quality of fishery products (*see also* Grading; Odours; Preservatives: *also* types of processing and products)
J 24(1): 9, (2): 221 (gamma-irradiated vs. non-irradiated lake whitefish; cooked lobster meat)
(1): 127 (water- vs. dielectric-thawed cod & redfish fillets)
(3): 527 (stored frozen Pac. dogfish)
(3): 651 (unfrozen Atlantic cod)
(11): 2229 (muscle hypoxanthine as test for freshwater fish)
B 160 (salmon & tuna chilled or frozen in refrigerated normal or fortified sea water)
CHN 30 (re flesh discoloration in gill-netted small Greenland halibut)
31 (frozen partially or wholly precooked lobsters)
S 1117 (review of postmortem changes in fish muscles minor organic constituents)
1175 (review of influence of lipid changes in frozen fish)
A 12(F), 65 (re fillet drip)
15 (nature of flavour in flesh foods)
26 (review of use of antibiotics for preserving)
27 (effect of environmental or physiological factors on Nfld. trap-caught cod)
28 (metal-catalyzed rancidity in Atl. groundfish)
29 (rigor changes in fish held in refrigerated sea water)
30 (enzymic degradation of glycogen & adenosine phosphate in fish muscle)
31 (assessment with Intelectron Fish Tester)
32 (enzymic removal of carbohydrates from fish muscle to inhibit browning)
41 (review of factors affecting)
69 (review of chemical changes in frozen fish muscle re organoleptic quality)
73 (as affected by condition of living fish, or season or stress of catching)

Quayle, Daniel Branch
J 24(4): 883 (plankton sampler for oyster larvae)

(12): 2637 (portable recompression chamber)
CNG 75 (paralytic shellfish poisoning)

Quebec Province (*see also* names of specific localities)
B 157 (lobster industry economic appraisal)
CHN 29 (capacities of fishmeal plants)

Queen Charlotte Islands region, B.C. (*see also* Dixon Entrance, Hecate Strait; Oceanography, B.C. coast; Oceanography, N Pac. Ocean)
J 24(10): 2101 (unusual fishes trawled off)
CNG 76 (shrimp exploration in Queen Charlotte Sound)
A 2 (B.C. Pacific cod trawl fishery)

Quillback (*Carpiodes cyprinus*)
J 24(2): 299 (muscle myogen electropherograms re speciation)

R

Rabbit
S 1173 (pyruvate metabolism in testes)

Racial studies
J 24(2): 443 (Atl. oysters)
(3): 629 (surf smelts)
(6): 1407 (lake char)
S 1137 (Pac. salmons in N Pac. Ocean)

Radiation (*see also* Irradiation; Light, reactions to)
J 24(11): 2283 (sunlight re lake phytoplankton productivity)

Raine, Gary Earnest
J 24(6): 1403 (lobster larvae low salinity avoidance)

Raja hyperborea (*see* Skate, Arctic)

Raja ocellata (*see* Skate, winter)

Raja radiata (*see* Skate, thorny)

Raleigh, Robert Franklin
J 24(12): 2613 (sockeye fry genetic control)

Rancidity, oxidative
J 24(3): 527 (in stored frozen Pac. dogfish)
S 1175 (of lipids re quality of frozen fish)
A 27, 73 (metal-catalyzed, in cod flesh, & for hastening tests of quality changes in frozen fish)
41 (studies review, Vancouver Station also antioxidants)

Range extensions (*see* Species, new records)

Ratfish (*Hydrolagus colliei*)
CNG 82 (1966 Hectate Strait exploratory fishing catches)

Rat-tail, roughscale (*Coryphaenoides acrolepis*)
J 24(5): 1101 (fatty acids composition)

Records, new (*see* Species, new; Species, new records)

Recruitment
J 24(2): 249 (re equilibrium yield: computerized Ricker model)
S 1148 (Atlantic cod variations re environmental changes)

Redds (*see* Spawning)

Redfish (*Sebastes marinus mentella*)
J 24(1): 127 (shell life of water- vs. dielectric-thawed fillets)
A 43 (1965 Canadian ICNAF studies)

Redfish (*Sebastes mentella*)
J 24(6): 1275 (pelagic adults in Labrador Sea)

Redhorse, golden (*Moxostoma erythrurum*)
J 24(2): 299 (muscle myogen electropherograms re speciation)

Redhorse, northern (*Moxostoma macrolepidotum*)
J 24(2): 299 (muscle myogen electropherograms re speciation)

Redhorse, silver (*Moxostoma anisurum*)
J 24(2): 299 (muscle myogen electropherograms re speciation)

Reduction (*see* Fishmeals; Oils)

Refrigeration (*see also* Chilling; Freezing)
J 24(1): 211 (desiccation of frozen cartoned sole fillets)
(3): 527 (stored frozen Pac. dogfish quality)
CHN 31 (frozen storage of preheated whole lobsters)
A 26 (fish & shellfish with antibiotics)
27, 28 (quality of frozen Atlantic cod)
55 (same as CHN 31 above)
69 (review of chemical changes in frozen fish muscle re organoleptic quality changes)

Regeneration
J 24(2): 433 (of bluespot goby scales)

Regulation (*see* Management)

Rehabilitation (*see also* Conservation; Hatchery)
J 24(2): 281 (by hatchery-reared lake trout, S Lake Superior)
A 35 (Atlantic oyster stocks)

Reinhardtius hippoglossoides (*see* Halibut, Greenland)

Relict species (*see* Species, relict)

Reproduction
J 24(2): 447 (tract anatomy, in trouts)
(3): 495 (isolation between pumpkinseed & bluegill sunfish)
(12): 2627 (breeding king crabs in ocean environment)
B 157: 15 (lobsters)
161: 22 (goldeye)

Respiration (*see also* Blood; Gills)
J 24(6): 1229 (& moulting of euphausids)
(11): 2267 (hematology of rainbow trout thermoacclimation)
(11): 2355 (mathematical model for fish)

Retallack, Mabel Elizabeth
J 24(11): 2497 (Japanese yew extract)

Reviews
J 24(2): 375 (Babine River sockeye salmon fry behaviour & ecology)
(4): 701–832 (effects of forest insecticide sprays on fish & aquatic insects)
S 1117 (postmortem changes in fish muscles minor organic constituents)
1123 (polychaete studies by E. and C. Berkeley)
1175 (influence of lipids changes on frozen fish quality)
A 1 (research on Nfld. commercial invertebrates)
15 (nature of flesh food flavours)
26 (antibiotic preservation of fish)
38 (phosphorus compounds in fish)
69 (chemical changes in frozen fish muscle re organoleptic quality)

Rhacochilus toxotes (*see* Seaperch, rubberlip)

Rhacochilus vacca (*see* Perch, pile)

Rhinichthys atratulus (*see* Dace, blacknose)

Rhinichthys cataractae (*see* Dace, longnose)

Ricker, William Edwin (*see also* Mathematical treatment)

Ridgway, George J.
J 24(4): 849 (marking Pac. salmon with tetracycline antibiotics)

Rigor
J 24(3): 651 (re Atlantic cod postmortem physiochemical changes)
(4): 873 (re protein in scallop striated muscle)
(8): 1717 (re Atlantic cod muscle adenosine monophosphate aminohydrolase)
(8): 1837 (nucleotide degradation, re postmortem changes in relaxed Atlantic cod muscle)
A 27 (re quality of Nfld. trap-caught cod)
29 (re changes in fish held in refrigerated sea water)
69 (re chemical changes in muscle as later affecting quality of frozen fish)

Roach, Stewart Williard
B 160 (chilling & freezing salmon & tuna in refrigerated sea water)
A 34 (new fish-unloading methods)

Roberts, Eve
J 24(2): 299 (Catostomidae electropherograms)

Rockfish, blackmouth (*Sebastodes crameri*)
J 24(9): 1945 (hemoglobin & muscle protein electropherograms)

Rockfish, blue (*Sebastodes mystinus*)
J 24(10): 2201 (in line fishing from ocean weathership P; identity doubtful)

Rockfish, redstripe (*Sebastodes proriger*)
J 24(9): 1945 (hemoglobin & muscle protein electropherograms)

Rockfish, sharpchin (*Sebastodes zacentrus*)
J 24(9): 1945 (hemoglobin & muscle protein electropherograms)

Rockfish, yellowmouth (*Sebastodes reedi*)
J 24(9): 1945 (new species, NE Pac., distinguished from muscle & hemoglobin protein electropherograms)

Rockfishes (Pacific)
CNG 82 (1966 Hectate Strait exploratory fishing catches)
CNS 28 (Canadian & U.S. trawl catches off B.C., 1954–65)
A 37 (fisheries potential)

Rockweeds (*Fucus* species)
J 24(1): 33 (*F. evanescens* vertical distribution, Indian Arm, B.C.)
S 1145 (optical activity of fucoxanthin *F. vesiculosis*)

Roe (*see* Eggs, fish)

Rostherne Mere, England
J 24(6): 1299 (limnology re guanotrophy)

Roy, Joan Elaine
S 1112 (incorporation of radioactive compounds)

Runoff (*see* Dilution effects; Estuary)

Rutherford, John Bow
B 157 (Canadian lobster fishery)

S

Saanich, Inlet B.C.
J 24(5): 909 (particulate matter continuous size spectrum)

Sable Island, N.S.
S 1190 (mammals on)

Sablefish (*Anoplopoma fimbria*) (blackcod)
J 24(2): 357 (α-tocopherol & lipids in tissues of unfed held)
(12): 2653 (composition of low-iodine-value fatty acids)
CNG 82 (1966 Hecate Strait exploratory fishing catches)
CNS 28 (Canadian & U.S. trawl catches off B.C., 1954–65)
A 21 (description, biology, handling, of B.C.)
37 (B.C. & U.S. trawl catches off B. C., 1956–63, & fisheries potential)
49 (description, habits, handling, age, & growth)

Sagamichthys abei (?) (a searsid fish)
J 24(10): 2101 (first record off B.C.)

Salinity, reactions to (*see also* Acclimation)
J 24(6): 1403 (newly hatched lobster larvae)

Salinity of marine waters (*see* Oceanography)

Salmo clarki (*see* Trout, cutthroat)

Salmo gairdneri (*see* Trout, rainbow; Trout, steelhead)

Salmo salar (*see* Salmon, Atlantic)

Salmo trutta (*see* Trout, brown)

Salmon, Atlantic (*Salmo salar*)
J 24(1): 21 (seasonal return pattern, Miramichi R., N.B.)
(4): 701, 709, 731, 769, 807 (& their insect feed, as affected by spraying insecticides to combat spruce budworm in N.B. forests)
(5): 955 (integument purines during parr to smolt)
(7): 1507 (thermal acclimation & temperature selection)
(7): 1515 (starvation effect on selected temperature)
(9): 1911 (as parasite host, Nfld.)
(12): 2595 (tagging vs. marking effects on growth & survival)
(12): 2639 (caught in Irminger Sea re Europe–Greenland migration)
S 1115 (transcortin binding of cortisol in female plasma)
1131 (in vitro hormone synthesis by gonad materials)
1135 (metabolism of pyruvate & glyoxalate by sperm)
A 24 (description; biology; feed; value; culture)
25 (Canadian-tagged recovered near Greenland)
43 (1965 Canadian ICNAF studies)
56 (high-seas tagging)

Salmon, chinook (*Oncorhynchus tshawytscha*) (*see also* Salmons, Pacific, inclusive)
J 24(1): 209 (juvenile adipose fin pigmentation for distinction from juvenile coho salmon)
(4): 843 (*Dermocystidium* fungus attack on prespawning adults)
(4): 849 (marking by incorporating antibiotic in vertebrae)
(4): 867 (histopathology of "gas bubble" diseased fingerlings)
S 1153 (plasma cortisol changes after stress of freshwater adults)

Salmon, chum (*Oncorhynchus keta*) (*see also* Salmons, Pacific, inclusive)
J 24(7): 1579 (as test for anesthesia & surgical techniques)
A 63 (description, migrations, reproduction, uses)

Salmon, coho (*Oncorhynchus kisutch*) (*see also* Salmons, Pacific, inclusive)
J 24(1): 209 (juvenile adipose fin pigmentation for distinction from juvenile chinook salmon)
(5): 1173 (toxicity of formamidin & hexachlorocyclohexane to young)
(6): 1421 (eating exotic earthworms)
(8): 1833 (botulinum spore germination in fillet extracts)
(10): 2201 (catches from ocean weathership P)
S 1184 (fatty acids composition of fingerlings)
A 48 (brief description; fishery methods)

Salmon, pink (*Oncorhynchus gorbuscha*) (*see also* Salmons, Pacific, inclusive)
J 24(1): 77 (fry behaviour in hatchery tank & after release)
(7): 1573 (ova & sperm fertility duration)
(7): 1629 (randomness in redds distribution)
(11): 2321 (orientation during early marine migration)
S 1156 (distribution, area of origin etc. in N Pac. Ocean)
1165 (microbial flora of stream-incubated eggs)
A 19 (forecast of runs by high-seas tagging)

Salmon, sockeye (*Oncorhynchus nerka*) (*see also* Salmons, Pacific, inclusive; Kokanee)
J 24(1): 67 (effects of feeding on thyroid, kidney, & pancreas of sexually ripening)
(2): 243 (flesh Na, K, & water content re sexual maturity & starvation)
(2): 375 (ecology & behaviour of Babine R. fry)
(4): 849 (marking by incorporating antibiotic in vertebrae)
(4): 893 (*Triaenophorus crassus* in Alaska smolts)

(5): 1117, (8): 1731 (stamina of naturally vs. artificially reared fry, re predation vulnerability & swimming ability)
(6): 1203 (binding of oil in canned)
(7): 1573 (ova & sperm fertility duration)
(8): 1775 (cardiovascular dynamics of swimming adults)
(8): 1791 (pituitary gland during sexual maturation & spawning
(9): 1955 (mate selection in mixed age-groups population)
(9): 1999 (gill raker number & length plasticity)
(10): 2069 (fry & smolts migratory behaviour in SW Alaska lakes)
(10): 2195 (unusual skin pigmentation)
(10): 2613 (genetic control in fry lakeward migrations)
CNS 25 (age, size, & sex ratio of B.C. 1912–63 catches)
S 1112 (testes tissue synthesis of nucleic acid derivates)
1129 (distribution, area of origin, etc., in N Pac. Ocean)
1153 (plasma cortisol changes after stress of adult freshwater)
1166 (orientation of young during [illegible]ward migration from lakes)
A 19 (forecast of runs by high-sea[illegible]ging)
26 (weight changes during rigor while held in refrigerated sea water)
30 (enzymic degradation of muscle glycogen & adenosine phosphate to inhibit flesh browning)
45 (description; migration; reproduction; fishing methods)

Salmons, Pacific, inclusive (*see also* individual species; *also* Kokanee; Trout, steelhead)
J 24(7): 1613 (standardized colour surfaces for grading canned)
(10): 2201 (catches from ocean weather-ship P)
B 160 (chilling & freezing in refrigerated sea water on vessels)
S 1137 (longline fishing, tagging, & racial study by INPFC in 1965)
A 7(F) (descriptions & life history)
52 (re oceanography)

Salt (sodium chloride)
S 1161 (living bacteria in N.S. carboniferous rock)

Salting; Salted products (*see also* Brines; Marination)
J 24(8): 1693 (Atlantic cod preparation by brining)

Salvelinus alpinus (*see* Char, arctic)

Salvelinus fontinalis (*see* Trout, brook)

Salvelinus namaycush (*see* Trout, lake)

Sampling; Sampling devices (*see also* Apparatus)
J 24(4): 883 (for planktonic oyster larvae)
(6): 1187 (statistical, for research trawl catches at sea)
(8): 1811 (small marine plankton)
(11): 2461 (new plastic-bag water sampler)
S 1154 (for gases in bottom sediments)

Sandeman, Ian Muir
J 24(7): 1627 (kill of *Salvelinus fontinalis* involving *Echinorhynchus lateralis*)
(9): 1911 (Nfld. freshwater fish parasites)

Sandercock, Frederick Keith
J 24(5): 965 (lake trout pyloric caeca and gill raker development)

Sarcina (bacteria)
S 1165 (on stream-incubated pink salmon eggs)

Sarcosine
S 1152 (oxidation by marine bacteria)

Sardine (Atlantic) (young Atlantic herring; *see* Herring, Atlantic)

Sardine, Pacific (*see* Pilchard)

Sardinops sagax (*see* Pilchard)

Sargassum muticum
J 24(1): 33 (vertical distribution, Indian Arm, B.C.)
S 1145 (optical activity of fucoxanthin from)

Satomi, Masako
J 24(11): 2467 (aquatic invertebrate retention)

Sauer, Charles Douglas
J 24(5): 1155 (digitized bathythermograph aperture cards)

Saunders, John Wilfred
J 24(8): 1743 (brook trout movements in an artificial pond)

Saunders, Richard Lee
J 24(1): 21 (seasonal return of salmon)
(12): 2595 (Atlantic salmon tagging and fin-clipping)
S 1126 (Greenland salmon fishery in Miramichi River, N.B.)
A 25 (Atlantic salmon near Greenland)

Saury, Pacific (*Cololabis saira*)
J 24(5): 1101 (fatty acids composition)

Saxidomus giganteus (*see* Clam, butter)

Scales, fish
J 24(1): 47 (formation re growth in young carp)
(2): 433 (regeneration in bluespot goby)
(5): 939 (effects of partial removal from live rainbow trout)

B 161: 6 (for determining goldeye age)
S 1129 (re sockeye salmon origins & distribution in N Pac. Ocean)
1156 (re pink salmon origins & distribution in N Pac. Ocean)
A 8(F) (for determining Atlantic herring age)

Scallop (*Pecten maximus*)
J 24(5): 1165 (shell-weight re age, Isle of Man)

Scallop, giant (*Placopecten magellanicus*) (sea scallop)
J 24(4): 873 (protein in striated muscle extracts)
S 1176 (efficiency & selectivity of 3 types of drags)
A 10(F), 64 (description; life history; Canadian fishery; use)
43 (1965 Canadian ICNAF studies)

Scallop, sea (*see* Scallop, giant)

Scarratt, David Johnson
J 24(6): 1403 (lobster larvae low salinity avoidance)

Schmidt, Peter Joseph
J 24(3): 527 (quality of dogfish during frozen storage)

Scomber scombrus (*see* Mackerel, Atlantic)

Scopelengys tristis (*see* Lanternfishes)

Scopelosaurus harryi (a scopelosaurid fish)
J 24(10): 2101 (first record off B.C.)

Scotian Shelf waters
S 1142 (long-term temperature variations)
1160 (trend-interpreting difficulties in cod & haddock landings from)

Scotoplanes theeli (a sea cucumber)
J 24(5): 1101 (fatty acids composition)

Sculpin, fourhorn (*Myoxocephalus quardricornis*)
A 14 (Great Bear Lake, N.W.T.)

Sculpin, mottled (*Cottus bairdi*)
J 24(5): 927 (limnetic larvae in N Wisconsin lakes)
S 1128 (in 4 Lake Superior bays)

Sculpin, slimy (*Cottus cognatus*)
S 1128 (in a Lake Superior bay)
A 14 (Great Bear Lake, N.W.T.)

Sea cucumbers
J 24(4): 833 (*Elpida glacialis* from a drifting ice island off E Greenland)
(5): 1101 (*Scotoplanes theeli* fatty acid composition)

Sea lettuce (*Ulva lactuta*)
J 24(1): 33 (vertical distribution, Indian Arm, B.C.)
S 1110 (photosynthesis in *Monostroma* & *Ulva*)

Sea lion, California (*Zalophus californianus*)
J 24(7): 1623 (anomalus records from Nfld.)

Sea stars (*see also* Starfish)
J 24(4): 833 (4 species from a drifting ice island off E Greenland)

Sea urchins (*see also* Urchin, heart)
J 24(4): 833 (*Strongylocentrotus droebachiensis* from a drifting ice island off E Greenland)
(6): 1377 (*Brisaster latifrons* re *B. townsendi*)
(6): 1385 (off Oregon, 10 species re bathymetric & geographic distribution)

Sea water, refrigerated (for holding fishery products)
B 160 (for chilling & freezing salmon & tuna)
A 26 (plus antibiotics for preserving fish quality)
29 (quality changes in fish passing through rigor while held in)
41 (review)

Seal, gray (*Halichoerus grypus*)
J 24(3): 635 (blubber oil fatty acids structure detail)
S 1190 (population on Sable Is., N.S.)
A 75 (Canadian Arctic tagging, 1965)

Seal, harbour (eastern Pacific) (*Phoca vitulina richardi*)
J 24(2): 435 (moulting of)
(2): 451 (pelage patterns re populations distributions)

Seal, harbour (western Atlantic) (*Phoca vitulina concolor*)
S 1118 (fatty acids positional distribution in blubber oil)
1188 (distribution in Canadian Arctic; possible identity with freshwater Ungava seal)
1190 (population on Sable Is., N.S.)

Seal, harp (*Pagophilus groenlandicus*)
A 43 (1965 Canadian landings)
75 (Canadian Arctic studies, 1965)

Seal, Ungava freshwater (*Phoca vitulina mellonae*)
S 1188 (possible identity with Atlantic harbour seal)

Seal pelts
CHN 28 (care & treatment of Atlantic)

Seaperch, pink (*Zalembius rosaceus*)
J 24(10): 2161 (parasitization re other surfperches)

Seaperch, rubberlip (*Rhacochilus toxotes*)
J 24(10): 2161 (parasitization re other surfperches)

Seaperch, striped (*Embiotoca lateralis*)
J 24(10): 2161 (parasitization re other surfperches)

Seaperch, white (*Phanerodon furcatus*)
J 24(10): 2161 (parasitization re other surfperches)

Seaweeds (*see also* Kelps; Sea lettuce; *also* names of species)
J 24(1): 33 (vertical distribution re environment, Indian Arm, B.C.)
S 1110 (photosynthesis in several Chlorophyceae)
1145 (optical activity of fucoxanthin)

Sebastodes alutus (*see* Perch, ocean (Pacific))

Sebastodes crameri (*see* Rockfish, blackmouth)

Sebastodes mystinus (*see* Rockfish, blue)

Sebastodes proriger (*see* Rockfish, redstripe)

Sebastodes reedi (*see* Rockfish, yellowmouth)

Sebastodes zacentrus (*see* Rockfish, sharpchin)

Sebastes marinus mentella (*see* Redfish)

Sebastes mentella (*see* Redfish)

Sediments
J 24(11): 2241 (bottom, of Kouchibouguac Bay, N.B.)
S 1154 (apparatus for sampling gases from bottom)
1155 (Coulter electronic counter for estimating suspended)

Selectivity of fishing gear
B 161: 39 (gill net mesh for goldeye)
S 1176 (3 types of scallop drags)

Sergeant, David Ernest
CAG 9 (whale species in western N Atl.)

Serology (*see also* Blood)
J 24(2): 443 (of 2 Atlantic oyster populations, re disease)
S 1129 (re sockeye salmon distribution in N Pac. Ocean)

Serrivomer sector (*see* Eels, snipe)

Serum (*see* Blood; Serology)

Sex ratio
J 24(1): 53 (Atlantic halibut re lengths & maturity)
(2): 305 (Ampelisca amphipods sibling pairs)
(7): 1425 (brook trout)
B 161: 22 (goldeye)
CNS 25 (B.C. sockeye salmon 1912–63 catches)
S 1128 (Lake Superior *Orconectes* crayfishes)

Sexual maturity (*see* Maturation)

Shad, gizzard (*Dorosoma cepedianum*)
J 24(2): 429 (lethal endrin polluant concentration in blood)

Shark, blue (*Prionace glauca*)
J 24(10): 2201 (in line fishing from ocean weathership P)

Shark, salmon (*Lamna ditropis*)
J 24(10): 2201 (in line fishing from ocean weathership P)

Shaw, William Neil
J 24(5): 1413 (freeze-drying shellfish for solids)

Sheepshead (*Aplodinotus grunniens*) (drum)
J 24(6): 1219 (oil yield & composition on reduction)
(6): 1291 (composition & nutritive value of meal)
S 1189 (oil fatty acids composition)
A (6)F (marinated fillets & similar products)

Sheldon, Raymond Wilfred
J 24(3): 569 (feeding and migration patterns of the pink shrimp)
(5): 909 (size spectrum for particle size in the sea)
(5): 1165 (shell weight and age in molluscs)
S 1155 (Coulter Counter)

Shell (*see also* Bivalves; Clam; Mollusca; Oyster)
J 24(5): 1165 (weight re age, of several British Isles aquatic molluscs)

Shellfish occasional toxicity
J 24(7): 1589 (growth & toxicity of causative *Gonyaulax tamarensis*)
CNG 75 (history, cause, nature, control, etc. on B.C. coast; safety precautions)

Shepard, Michael Perry
A 19 (high-seas tagging of salmon runs)

Shetter, David Sibley
J 24(7): 1425 (*Salvelinus fontinalis* numerical changes and population regulation)

Shieh, Hang-shan
S 1152 (formaldehyde isolation)
1178 (choline or betaine utilization)

Shiner, common (*Notropis cornutus*)
S 1128 (in 2 Lake Superior bays)

Shiner, emerald (*Notropis atherinoides*)
J 24(5): 927 (limnetic larvae in N Wisconsin lakes)

Shiner, spottail (*Notropis hudsonius*)
S 1128 (in 4 Lake Superior bays)

Shiners (*Notropis* species)
S 1128 (*N. deliciosus*, etc., in Lake Superior bays)

Shipping
A 4(F) (precautions for, live lobsters)

Shipworms
J 24(2): 261 (estimating attack of *Bankia setacea* on wood)

Shrimp (a deepsea) (*Acanthephyra curtirostris*)
J 24(5): 1101 (fatty acids composition)

Shrimp, coonstripe (*Pandalus danae*)
A 50 (description)

Shrimp, giant red (*see* Shrimp, sidestripe)

Shrimp, humpback (*Pandalus hypsinotus*) (king shrimp)
CNG 76 (exploration in Hecate Strait & Queen Charlotte Sound, B.C., 1966)
A 50 (description)

Shrimp, king (*see* Shrimp, humpback)

Shrimp, pink (Canada) (*Pandalus borealis*)
J 24(2): 467 (fatty acids composition)
(8): 1833 (botulinum spore germination in tissue extracts)
CNG 76 (exploration in Hecate Strait & Queen Charlotte Sound, B.C., 1966)
A 50 (description)

Shrimp, pink (England) (*Pandalus montagui*) (striped pink shrimp in Canada)
J 24(3): 569 (feeding & migration in a British river)

Shrimp, sidestripe (*Pandalopis dispar*) (giant red shrimp)
CNG 76 (exploration in Hecate Strait & Queen Charlotte Sound, B.C., 1966)
A 50 (description)

Shrimp, smooth pink (*Pandalus jordani*)
CNG 76 (exploration in Hecate Strait & Queen Charlotte Sound, B.C., 1966)
A 50 (description)

Shrimp, spot (*see* Prawn)

Shrimp, striped pink (*see* Shrimp, pink (England))

Shrimps in general (*see also* Prawn)
J 24(3): 683 (pot for experimental fishing, Alaska)
CNG 79 (Japanese catches in N Pac., 1963–66)
A 50 (B.C. fishery landings, 1939–65; fishery methods)
60 (same as CNG 79 above)

Shrinkage
J 24(3): 691 (in groundfish length measurements)

Shumway, Dean Lee
J 24(3): 475 (oxygen on largemouth bass growth)

Sibbaldus musculus (*see* Whale, blue)

Sight (*see* Eye; Light, reactions to)

Siliqua patula (*see* Clam, razor)

Silt (*see* Sediments)

Simuliidae (*see* Flies, black)

Sinclair, Sol
B 158 (fisheries of District of Mackenzie)

Sipos, John Charles
J 24(3): 613 (seasonal changes in cod fatty acid composition)
(3): 635 (marine fatty acids)
S 1136 (fatty acid methyl esters storage)
1177 (cod liver lipids fatty acid esters)

Size; (*see also* Growth; Length; Weight)
J 24(1): 53 (Atlantic halibut at maturity)
(2): 375 (Babine R. sockeye salmon fry)
(5): 909 (continuous size spectrum for marine particulate matter)
(9): 1945 (composition of new species *Sebastodes reedi*)
B 157: 21 (distribution of lobsters)
161: 11, 19 (goldeye)
CHN 30 (re flesh discoloration of gill-netted Greenland halibut)
CNS 25 (composition of B.C. sockeye salmon 1912–63 catches)

Skate, Arctic (*Raja hyperborea*)
J 24(1): 215 (predation by amphipod)

Skate, thorny (*Raja radiata*)
J 24(1): 205 (mineralocorticoid activity of blood steroid for rat)
S 1114, 1141 (hormones in blood plasma)
1167, 1168 (in vitro biosynthesis of 1α-hydroxycorticosterone by interrenal tissue)
A 11(F) (hormones in blood plasma)

Skate, winter (*Raja ocellata*)
J 24(1): 205 (mineralocorticoid activity of blood steroid for rat)
S 1114 (testosterone in blood plasma)
1167, 1168 (in vitro biosynthesis of 1α-hydroxycorticosterone by interrenal tissue)
A 11(F) (hormones in blood plasma)

Skeleton (*see* Cranium; Jaw; Osteology; Vertebrae)

Skeletonema (*see* Diatoms; Phytoplankton)

Skidmore, John Frederick
J 24(6): 1253 (zebrafish oxygen uptake and zinc sulphate resistance)

Skilfish (*Erilepis zonifer*)
J 24(10): 2201 (in line fishing from ocean weathership P)

Skin (*see also* Pelage; Pelts; Scales)
J 24(5): 955 (purines in Atlantic salmon integument during parr to smolt)
(10): 2195 (unusual pigmentation of sockeye salmon)
S 1140 (bacterial lesions on rainbow trout)
A 58 (cause, control, & treatment of "swimmers' itch," from dermatitis on human)

Skull (*see* Cranium; Jaw; Teeth)

Slickhead (*Bajacalifornia burragei*)
J 24(5): 1101 (fatty acids composition)

Slack, Harry Dawson
J 24(5): 1017 (profundal benthic fauna of Man. lakes)

Slime (mucus)
J 24(5): 939 (effects of partial removal from live rainbow trout)
A 29 (effects of removal on weight changes of trout held in refrigerated sea water)

Slusar, Isabel Marie
J 24(1): 9 (whitefish preservation with radiation)

Smelt (deepsea) (*see* Smoothtongue, California)

Smelt, American (*Osmerus mordax*)
S 1128 (in a Lake Superior bay)
A 13(F) (description; value; distinction from other similar fishes)
39 (description; life history in Lake Erie & Miramichi R.; fisheries)

Smelt, surf (*Hypomesus pretiosus*)
J 24(3): 629 (heterogeneity of Washington State populations)

Smith, Howard Donald
J 24(9): 1955 (sockeye mate selection)

Smith, John William
J 24(8): 1763 (*Aporocotyle margolisi* n.sp.)

Smith, Lynwood Stephen
J 24(7): 1579 (Pac. salmon anesthetic and surgical techniques)
(8): 1775 (sockeye cardiovascular dynamics)

Smith, Morden Whitney
J 24(8): 1743 (brook trout movements in an artificial pond)
S 1132 (fish-eating birds and mammals at Crecy Lake, N.B.)
1133 (hatchery-reared trout movement from a natural lake)
A 24 (Atlantic salmon)
57(F) (artificial trout ponds)

Smoking
B 161: 35 (goldeye)

Smolts (*see* headings relating to young salmons)

Smoothtongue, California (*Leuroglossus stilbius*)
J 24(5): 1101 (fatty acids composition)

Snail, mud (*Nassarius obsoletus*)
A 58 (carrier of parasitic cercariae larvae causing "clam-diggers' itch" dermatitis in humans)

Snails, freshwater
A 58 (*Lymnaea emarginata, L. stagnalis,* & *Physa* as carriers of cercariae parasitic larvae causing "swimmers' itch" dermatitis on humans)

Sodium compounds (*see also* Salt)
J 24(2): 243 (in sockeye salmon flesh re sexual maturity & starvation)
(10): 2169 (sulphite effect on rainbow trout blood serum proteins)
S 1162 (sulphate activity coefficient in sea water)
A 29 (changes in flesh of fish held in refrigerated sea water)

Sole (Pacific)
J 24(1): 211 (desiccation of stored cartoned frozen fillets)

Sole, Dover (*Microstomus pacificus*)
CNG 82 (1966 Hecate Strait exploratory fishing catches)
CNS 28 (Canadian & U.S. trawl catches off B.C., 1954–65)
A 37 (B.C. & U.S. landings, 1956–63, & fisheries potential)

Sole, lemon (Pacific) (*Parophrys vetulus*) (English sole)
J 24(3): 691 (shrinkage factor in measuring lengths)
(8): 1833 (botulinum spore germination in fillet extracts)
CNG 82 (1966 Hecate Strait exploratory fishing catches)
CNS 28 (Canadian & U.S. trawl catches off B.C., 1954–65)
A 37 (B.C. & U.S. landings, 1956–63, & fishery potential)
46, 51(F) (brief description)

Sole, petrale (*Eopsetta jordani*) (Brill (Pacific))
J 24(3): 691 (shrinkage factor in measuring lengths)
CNG 82 (1966 Hecate Strait exploratory fishing catches)

CNS 28 (Canadian & U.S. trawl catches off B.C., 1954–65)
A 37 (B.C. & U.S. landings, 1956–63, & fishery potential)
46, 51(F) (brief description)

Sole, rex (*Glyptocephalus zachirus*)
CNS 28 (Canadian & U.S. trawl catches off B.C., 1954–65)

Sole, rock (*Lepidopsetta bilineata*)
J 24(3): 691 (shrinkage factor in measuring lengths)
CNG 82 (1966 Hecate Strait exploratory fishing catches)
CNS 28 (Canadian & U.S. trawl catches off B.C., 1954–65)
A 37 (B.C. & U.S. catches, 1956–63, & fishery potential)
46, 51(F) (brief description)

Sole, sand (*Psettichthys melanostictus*)
J 24(12): 2515 (stomach contents of adult)

Sound, reactions to
J 24(11): 2309 (Atlantic cod audiogram)

South Bay, Manitoulin Is. (Lake Huron, Ont.)
J 24(1): 87 (smallmouth bass growth re temperature)
(1): 101 (thermal regime re growth of various fishes)
(10): 2117 (white sucker population re lamprey invasion)

Southcott, Burnett Anne
J 24(1): 211 (desiccation of frozen fish)
(3): 527 (quality of dogfish during frozen storage)

Sparks, Albert Kirk
J 24(10): 2155 (*Ostrea lurida* and *Crassostrea* chromosomes)

Spawning (*see also* Eggs, fish; Life history; Migration; etc.)
J 24(1): 21 (migration seasonal pattern, N.B. salmon)
(1): 53 (re size, Atlantic halibut)
(7): 1629 (randomness in pink salmon redds distribution)
(8): 1791 (of sockeye salmon re pituitary)
(9): 1955 (mate selection, sockeye salmon)
(12): 2573 (& development of Atlantic cod in Ogac Lake, Baffin Is.)
B 161: 23, 25 (goldeye)
CNG 77, 83 (abundance of herring, B.C., 1966; 1967)
A 36 (habits, Pacific herring)
59 (of B.C. herring in 1966 lowest on record)
62 (same as A 59 above)

Spears, Doris Isabel
S 1178 (choline or betaine utilization)

Speciation (*see also* Key)
J 24(1): 1 (North Pacific prickleback; correction on J 24(12): 2641)
(2): 299 (Catostomidae, by muscle myogen electropherograms)
(6): 1315 (Gadidae subfamily origins through cranium osteology)
(6): 1377 (*Brisaster latifrons* vs. *B. townsendi*)

Species, new
J 24(2): 231 (*Gaidius columbiae* & *Tharybis fultoni* copepods)
(8): 1763 (*Aporocotyle margolisi* parasitic trematode)
(9): 1911 (trematode *Phyllodistomum limnosa*; parasitic copoped *Salmonicola exsanguinata*)
(9): 1945 (yellowmouth rockfish (*Sebastodes reedi*) from NE Pac.)
(9): 2003 (bryozoa *Figularia quaylei* from NE Pac.)
(12): 2629 (clam *Cuspidaria cowani* off Queen Charlotte Is.)
S 1139 (*Discoasteromonas calciferus* flagellate as arctic relict)

Species, new records or range extensions of
J 24(1): 213 (fawn cusk-eels N to southern N.S.)
(1): 215 (amphipod *Eurythenes gryllus* W in Baffin Bay)
(5): 1177 (gempylid fish *Nealotus tripes* off Sable Is. bank)
(6): 1385 (echinoids off Oregon)
(6): 1421 (earthworms in B.C.)
(7): 1623 (California sea lion off Nfld.)
(9): 1873 (decapod crustacean *Eualus macilentus* in Hudson Bay)
(10): 2101 (first & second records of various deepsea fishes off B.C.)
(12): 2631 (Atlantic walrus into Nfld. waters)
S 1138 (polychaetes, B.C. waters)
A 75 (first Bering flounder & third Bering wolffish recorded from central Canadian Arctic)

Species, relict
S 1139 (*Discoasteromonas calciferus* flagellate)
1191 (*Distephanus speculum* silicoflagellate & *Gymnaster pentasterias* dinoflagellate in Great Bear Lake, N.W.T.)

Speed of swimming (*see* Swimming)

Sperms (*see* Milt; Testes)

Sperosoma giganteum (*see* Sea urchins)

Sphyrion lumpi (parasitic copepod)
J 24(6): 1275 (on & in pelagic redfish)

Spisula solidissima (*see* Clam, Atlantic surf)

Sport fishing (*see also* Angling)
A 16 (summary of symposium on economics of)

Sprules, William Memberry
B 161 (goldeye in Canada)

Squalus acanthias (*see* Dogfish, spring)

Squalus suckleyi (*see* Dogfish, Pacific)

Squid, short-finned (*Illex illecebrosus illecebrosus*)
J 24(6): 1209 (growth & hypothetical age, of Nfld. bait)
S 1130 (feeding habits)
A 43 (1965 Canadian ICNAF studies)

Squires, Hubert Jacob
J 24(6): 1209 (growth and age of *Illex illecebrosus illecebrosus*)
(9): 1873 (Crustacea in Hudson Bay)
S 1130 (squid feeding habits)
A 1 (marine invertebrates)

St. Andrews, N.B.
S 1142, 1143, 1148 (surface seawater temperatures & forecasts of)

Starfish, brittlestar
J 24(4): 833 (8 species from a drifting ice island off E Greenland)

Starfish, sea star (*see* Sea stars)

Starvation effect
J 24(2): 243 (re sockeye salmon sexual maturity & flesh Na, K, & water content)
(2): 357 (on muscle α-tocopherol & lipids in unfed fish & shellfish)
(7): 1515 (on salmonids -selected temperature)

Statistics (*see* Mathematical treatment)

Steaks
J 24(7): 1461 (freeze-drying Atlantic cod)

Stendall, Rey Carl
J 24(4): 833 (E Greenland echinoderms)

Stenella euphrosyne (*see* Dolphin, euphrosyne)

Stenodus leucichthys (*see* Inconnu)

Steroids; Sterones (*see* Hormones)

Stevenson, James Cameron
B 161 (Foreword to Bulletin on goldeye in Canada)

Stewart, Gene Lloyd
J 24(8): 1811 (pumping system for plankton)
(10): 2053 (micro-zooplankton in euphotic zone across California Current)

Stewart, James Edward
J 24(2): 443 (serological differences between 2 Atl. coast oysters)
(11): 2339 (lobster muscle weight)
(12): 2623 (gaffkemia susceptibility)
S 1119 (*Homarus americanus* hemolymph constituents)
1125 (lobster triglyceride digestion)
1144 (lobster hemocytes)

Stewart, Nelson Eugene
J 24(3): 475 (oxygen on largemouth bass growth)

Stickleback, brook (*Eucalia inconstans*)
S 1128 (in 2 Lake Superior bays)

Stickleback, ninespine (*Pungitius pungitius*)
S 1128 (in 2 Lake Superior bays)
A 14 (Great Bear Lake, N.W.T.)

Stickleback, threespine (freshwater) (*Gasterosteus leiurus*)
J 24(8): 1637 (reproductive isolating mechanisms)

Stickleback, threespine (marine) (*Gasterosteus trachurus*)
J 24(8): 1637 (reproductive isolating mechanisms)

Stizostedion vitreum glaucum (*see* Pike, blue)

Stizostedion vitreum vitreum (*see* Walleye)

Stocks (*see also* Populations; Rehabilitation; *also* names of organisms)
J 24(2): 249 (Ricker method of predicting yield per recruitment)
(5): 1117 (swimming stamina as quality test)
(12): 2527 (mathematical treatment of exploitation of multiple)
B 157: 19 (of legal-size lobsters re Canadian fishery economics)
S 1126 (effect of Greenland salmon fishery on N.B. salmon stocks & fishery)
1129 (sockeye salmon in offshore N Pac. Ocean)
1147 (haddock off E Canada coast)
1156 (pink salmon in offshore N Pac. Ocean)
A 18 (unexploited, re challenge of exploration & new fishing methods)
35 (rehabilitation of Atlantic oyster)

Stomach contents (*see* Feed)

Stoneflies
J 24(4): 769, 823 (affected by N.B. forest insecticide sprays, re their role as salmon & trout feed)
S 1128 (in benthos of 4 Lake Superior bays)

Strasdine, George Alfred
J 24(3): 595 (*Clostridium botulinum* type E spores)
(8): 1833 (*Clostridium botulinum* type E in fish and shellfish extracts)

Stress (*see also* Activity)
J 24(8): 1775 (cardiovascular dynamics of swimming adult sockeye salmon)
(10): 2169 (serum protein of rainbow trout after various)
S 1153 (adult freshwater sockeye salmon plasma cortisol after)
A 29 (pre-mortem, re weight changes of fish held post-mortem in refrigerated sea water)

Strickland, John Douglas Hipwell
J 24(8): 1811 (pumping system for plankton)

Stringer, George Everett
J 24(2): 463 (*Mysis relicta* in B.C.)

Strongylocentrosus purpuratus, S. franciscanus, S. echinoides, S. droebachiensis (*see* Sea urchins)

Stutz, Sherwood Simpson
J 24(2): 435 (moult in the Pac. harbour seal)
(2): 451 (Pac. harbour seal pelage patterns and distribution)

Sucker, longnose (*Catostomus catostomus*)
J 24(2): 299 (muscle myogen electropherograms re speciation)

Sucker, spotted (*Minytrema melanops*) (*Moxostoma melanops*)
J 24(2): 299 (muscle myogen electropherograms re speciation)

Sucker, white (*Catostomus commersoni*) (common sucker)
J 24(2): 299 (muscle myogen electropherograms re speciation)
(5): 927 (limnetic larvae in N Wisconsin lakes)
(10): 2117 (effects of sea lamprey on a Lake Huron population)
S 1128 (in 2 Lake Superior bays)
A 6(F) (marinated fillets & similar products)
14 (Great Bear Lake, N.W.T.)

Suctoria
J 24(9): 1911 (parasitic on Nfld. freshwater fishes)

Sugars (*see also* Glucose)
S 1110, 1183 (re algae photosynthesis)
1117, 1124 (review of postmortem changes in fish muscles)
A 30, 32 (enzymic degradation of sugars & sugar phosphates in fish flesh to inhibit browning)

Sulphur compounds (*see also* Sodium compounds; Thetin derivatives)
J 24(2): 457 (dimethyl sulphide re blackberry flesh condition of Labrador cod)
S 1110, 1159 (dimethyl sulphide liberation from alga photosynthesis products)
1157 (apparatus for hydrogen sulphide oxidation kinetics)
1180 (removal of fish tank brown stain by sulphur dioxide)
A 40 (same as S 1159 above)

Sunfish (*see* Bluegill; Pumpkinseed)

Sunfish, green (*Lepomis cyanellus*)
J 24(3): 695 (blood low-mobility proteins)

Superior, Lake
J 24(2): 281 (hatchery-reared lake trout returns)
(2): 299 (Catostomidae speciation)
(4): 887 (rainbow trout phenotypic characteristics)
S 1128 (benthos of 4 bays)

Surfperch, barred (*Amphistichus argenteus*)
J 24(10): 2161 (parasitization re other surfperches)

Surfperch, spotfin (*Hyperprosopon anale*)
J 24(10): 2161 (parasitization re other surfperches)

Surfperch, walleye (*Hyperprosopon argenteum*)
J 24(10): 2161 (parasitization re other surfperches)

Surfperches (Embiotocidae)
J 24(10): 2161 (specificity as parasite hosts)

Surgery
J 24(7): 1579 (techniques for Pac. salmon)

Survival (*see also* Life History; Predation; *also* names of individual species)
J 24(12): 2595 (effects of tagging vs. marking on young Atlantic salmon)

Swee, U Boon
J 24(1): 47 (young carp scale formation)

Swiftsure Bank (off Vancouver Is., B.C.)
J 24(8): 1827, (11): 2207 (oceanographic studies of)

Swimming; Swimming speed
J 24(5): 1117, (8): 1731, 1775 (of migrant sockeye salmon fry as stamina test)
(6): 1241 (new apparatus for measuring for small fishes)
S 1166 (activity re orientation of seaward migrating young sockeye salmon)

Swimmers' itch
A 58 (cause, control, & treatment)

Swordfish (*Xiphias gladius*)
A 43 (1965 Canadian ICNAF studies)

Symphurus atricauda (*see* Tonguefish, California)

T

Tacreiter, Wanda Danuta
S 1125 (lobster triglyceride digestion)

Tagging methods, returns, losses, and interpretation (*see also* Marking; Migration)
J 24(1): 21 (Atlantic salmon grilse returns, Miramichi R., N.B.)
(3): 495 (2 sunfish species, re interspecific breeding)
(9): 1991 (re young bluefin tuna transatlantic migrations)
(10): 2011 (cutthroat trout with attached floats)
(10): 2117 (Lake Huron white suckers)
(12): 2595 (vs. marking effects on young Atlantic salmon survival & growth)
S 1129 (sockeye salmon in N Pac. Ocean re distribution)
1137 (salmons in N Pac. Ocean re distribution)
1156 (pink salmon in N Pac. Ocean re distribution)
A 19 (forecasting pink & sockeye runs by high-seas tagging)
25 (recovery of Atlantic salmon near Greenland)
56 (on high seas re Atlantic salmon movements)
75 (gray seals & Greenland cod in Canadian Arctic, 1965)

Tank, fish (*see also* Sea water, refrigerated)
S 1180 (use of sulphur dioxide to remove brown stains)

Tanquary Fjord, Ellesmere Island (Canada Arctic)
J 24(3): 555 (zooplankton, especially calanoid copepods)

Tapeworm
J 24(4): 893 (*Triaenophorus crassus* plerocercoids in Alaska sockeye salmon smolts)

Tarletonbeania crenularis (*see* Lanternfish, blue)

Tarr, Hugh Lewis Aubrey
B 160 (chilling and freezing salmon and tuna in refrigerated sea water)
S 1112 (incorporation of radioactive compounds)
1117 (fish muscle postmortem changes)
1124 (sugars in fish muscles postmortem)
A 15 (flavor of flesh foods)
26 (fish preservation by antibiotics)
30 (fish muscle degradation of glycogen and adenosine 5′-triphosphate)
32 (carbohydrate removal from fish muscle)
38 (fish phosphorus compounds)
41 (Pac. coast fisheries technological developments)

Taste panels (*see* Quality of fishery products)

Taxonomy (*see also* Nomenclature)
J 24(1): 1 (North Pacific pricklebacks)

Taxus cuspidata (*see* Yew, Japanese)

Taylor, Frederick Henry Carlyle
J 24(10): 2101 (unusual fishes trawled off B.C.)
CNG 80 (B.C. herring)

Teeth
J 24(5): 1067 (of lampreys, & key based on teeth)
(12): 2503 (of stranded Cuvier's beaked whale)

Temperature, water (reactions to)
J 24(1): 87 (re smallmouth bass adult total annual growth)
(1): 101 (re growth of various fishes, Georgian Bay, Ont.)
(1): 191 (re electronarcosis of trout)
(7): 1507 (acclimation & selection by rainbow trout and Atlantic salmon)
(7): 1515 (starvation effect on, Atlantic salmon & rainbow trout)
(8): 1731 (re sockeye salmon fry swimming stamina)
(10): 2069 (migrating sockeye salmon fry & smolts)
(11): 2372 (re mathematical model for fish growth)

Temperature of natural waters (*see also* Limnology; Oceanography; *also* names of lakes and other bodies of water)
J 24(5): 1155 (digitizing system for bathythermograph cards)
(11): 2473 (demonstrated in model of a lake)
(11): 2491 (computer vs. manual calculations)
S 1142, 1143 (long-term variations in Scotian Shelf area)
1147 (bottom, re haddock distribution)
1148 (re Atlantic cod recruitment off N.S.)
1149 (re herring fishery off Magdalen Is.)

Templeman, Wilfred
J 24(1): 215 (predation on living fishes by *Eurythenes gryllus*)
(6): 1275 (adult redfish in Labrador Sea)
S 1127 (ICNAF research, Subareas 1–3, 1965)
A 43 (ICNAF research, Subareas 1–5)

Tench (*Tinca tinca*)
J 24(11): 2355 (oxygen consumption re weight loss in fasting)

Terhune, Lorne Donald Bruce
J 24(4): 883 (plankton sampler for oyster larvae)

Tessarabrachion oculatus (a euphausid)
J 24(6): 1229 (moulting & respiration)

Testes (*see also* Milt)
S 1112 (trout & salmon tissue synthesis of nucleic acid derivates)
1131 (in vitro hormone synthesis by material from Atlantic salmon)
1173 (pyruvate metabolism in rabbit & Atlantic cod)

Testosterone (*see* Hormones)

Tetracycline derivatives (*see* Antibiotics, tetracycline)

Tetraselmis (dinoflagellate algae)
S 1110, 1189 (photosynthesis in several species)

Testure (*see* Quality of fishery products)

Thais lapillus (*see* Dogwinkle, Atlantic)

Thaleichthys pacificus (*see* Eulachon)

Tharybis fultoni (a copepod)
J 24(2): 231 (new species, B.C.)

Thawing
J 24(1): 127 (effect of water vs. dielectric on shelf life of cod & redfish fillets)
A 69 (effects on frozen fish muscle & on refrozen muscle)

Theragra chalcogrammus (*see* Pollock, walleye)

Thermocline (*see also* Limnology; Oceanography)
A 52 (description & significance of oceanic)

Thetin derivatives
J 24(2): 457 (re blackberry flesh condition & dimethyl sulphide odour in Labrador cod)
S 1110, 1159 (produced during green alga photosynthesis)
A 40 (same as S 1159 above)

Thompson, John Arthur
CNG 82 (Hecate Strait groundfish, 1966)
A 74 (Dixon Entrance groundfish area)

Thomas, Martin Lewis Hall
S 1122 (eelgrass control in oyster growing areas)
1128 (benthos of 4 Lake Superior bays)
1169 (*Thracia conradi*)

Thunnus alalunga (*see* Albacore)

Thunnus albacares (*see* Tuna, yellowfin)

Thunnus thynnus (*see* Tuna, bluefin)

Thurston, Robert Vance
J 24(10): 2169 (trout blood serum proteins electrophoretic patterns)

Thymallus arcticus (*see* Grayling, arctic)

Thyroid
J 24(1): 67 (effect of feeding on, in sexually ripening sockeye salmon)

Thysanoëssa (euphausids)
J 24(6): 1229 (moulting & respiration of *T. spinifera*, *T. raschii*, & *T. longipes*)

Tibbo, Simeon Noel
S 1149 (Magdalen Is. herring fishery)
1150 (light on herring movements)
A 8(F) (Atlantic herring)
9(F) (Atlantic mackerel)
67 (bluefin tuna)

Tide (*see also* Oceanography)
J 24(11): 2321 (effect on pink salmon fry early marine migration)
B 156: 29 (mechanism, Dixon Entrance, B.C.)

Tigerstrom, Richard von
A 32 (carbohydrate removal from fish muscle)

Tinca tinca (*see* Tench)

Tocher, Carol Ann Shipton
J 24(3): 635 (marine fatty acids)
S 1110 (photosynthesis in green algae)
1159 (dimethyl-β-propiothetin)
1183 (photosynthesis in algae)
A 40 (dimethyl-β-propiothetin)

Tocopherol, α-
J 24(2): 357 (in Atl. fish & shellfish muscle after unfed holding)
S 1175 (re lipid changes effects on frozen fish quality)

Tomlinson, Neil
J 24(2): 243 (flesh of salmon)
(8): 1701 (trout catecholamine and carbohydrate concentrations)
B 160 (chilling and freezing salmon and tuna in refrigerated sea water)
A 29 (fish in rigor mortis in refrigerated sea water)

Tonguefish, California (*Symphurus atricauda*)
J 24(5): 1101 (fatty acids composition)

Toxicants for fishes (*see also* Insecticides)
J 24(2): 429 (lethal endrin content in gizzard shad blood)
(8): 1819 (3-trifluormethyl-4-nitrophenol vs. anoxia effects on sea lamprey)

Toxicity (*see also* Insecticides; Pollution; Shellfish occasional toxicity)
J 24(7): 1589 (comparison of *Gonyaulax tamarensis* & *G. catenella* toxins)
CNG 75 (comparison of *G. catenella* & *G. acatanella* habits and toxicities on B.C. coast)

Trachtenberg, Samuel
B 158 (fisheries of District of Mackenzie, N.W.T.)

Trachurus symmetricus (*see* Mackerel, jack)

Transport, mass (of waters)
J 24(3): 581 (Ekman, re NE Pac. zooplankton concentration)
B 156: 15 (Ekman, in Dixon Entrance, B.C.)

Transportation of fishery products (*see* Handling; Pumps; Sea water, refrigerated)

Trawl; Trawling
J 24(6): 1187 (sampling research catches at sea)
CNG 76 (gear for B.C. shrimps exploration)
78 (review of B.C. Pacific cod fishery & 1967 forecast)
79 (groundfish catches by different nations off B.C.)
82 (in B.C. groundfish exploratory fishing, 1966)
CNS 28 (1954–65 production by Canadian & U.S. vessels off B.C.)
A 2 (B.C. trawl fishery)
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74 (summary of CNG 82 above)

Tredwell, S. J.
J 24(5): 939 (scale loss in rainbow trout)

Trematoda
J 24(8): 1763 (*Aporocotyle margolisi* (n.sp.) found in Pacific hake)
(9): 1911 (descriptions of parasitic on Nfld. freshwater fishes)

Triaenophorus crassus (*see* Tapeworm)

Trichoptera (*see* Caddisflies)

Triglycerides (*see also* Acids, fatty; Lipids; Oils and fats)
S 1125 (digestive hydrolysis by lipase of lobster)
1170 (alternative method for stereospecific analysis of)
1186 (conversion of dietary into depot fat by fish & lobster)

Trimethylamine
J 24(2): 221 (values of irradiated cooked lobster meat)

Triphoturus mexicanus (*see* Lanternfishes)

Trout, brook (*Salvelinus fontinalis*) (speckled trout)
J 24(2): 447 (urinary & genital systems anatomy)
(3): 695 (blood low-mobility proteins)
(4): 701, 709, 769, 823 (& their insect feed, as affected by spraying insecticides to combat spruce budworm in N.B. forests)
(7): 1425 (numerical changes & population regulation in Hunt Creek, Michigan)
(7): 1515 (starvation effect on selected temperature)
(7): 1627 (death from *Echinorhynchus lateralis* spiny headed worm parasite)
(8): 1743 (movements re artificial pond en route to sea)
(9): 1911 (as parasite host, Nfld.)
(11): 2402 (mathematics of oxygen consumption)
S 1132 (predation by birds, Crecy Lake, N.B.)
1133 (movements of planted hatchery-reared, from Crecy Lake, N.B.)
1186 (biosynthesis of depot fat from dietary triglycerides)
A 57(F) (establishment & management of rearing in artificial ponds in Canadian Maritimes)

Trout, brown (*Salmo trutta*)
J 24(1): 191 (response factors in fresh- & saltwater electric field)
(2): 447 (urinary & genital systems anatomy)
(3): 695 (blood low-mobility proteins)
(9): 1911 (as parasite host, Nfld.)
A 57(F) (establishment & management of rearing in artificial ponds in Canadian Maritimes)

Trout, cutthroat (*Salmo clarki*)
J 24(10): 2011 (olfaction & vision re homing & orientation)

Trout, lake (*Salvelinus namaycush*) (*Cristivomer namaycush*)
J 24(2): 281 (returns of hatchery-reared, S Lake Superior)
(2): 447 (urinary & genital systems anatomy)
(5): 965 (pyloric caeca & gill raker development)
(6): 1407 (morphological comparison of 3 populations)
B 158 (physical & economic organization of N.W.T. fishery)
A 14 (Great Bear Lake, N.W.T.)

Trout, rainbow (*Salmo gairdneri*) (*see also* Trout, steelhead)
J 24(2): 273 (choline derivatives of muscle stored at –4 C)
(2): 447 (urinary & genital systems anatomy)
(2): 463 (*Mysis relicta* introduced into lakes as feed)
(3): 695 (blood low-mobility proteins)
(4): 849 (marking by incorporating antibiotic in vertebrae)
(4): 887 (phenotypic characteristics in Great Lakes)
(5): 939 (effect of partial scale & slime removal from live)

(7): 1507 (thermal acclimation & temperature selection)
(7): 1515 (starvation effect on selected temperature)
(7): 1607 (muscle myogen amino acids)
(8): 1693 (catecholamine & carbohydrate concentrations in, re physical disturbance of)
(9): 1911 (as parasite host, Nfld.)
(10): 2169 (blood serum proteins after various stresses)
(11): 2267 (hematology of thermoacclimation)
(12): 2555 (muscle phospholipase A activity)
(12): 2539 (parasitism by Georgian Bay sea lampreys)
S 1112 (testes tissues synthesis of nucleic acid derivatives)
1132 (predation by birds, Crecy Lake, N.B.)
1133 (movement of planted hatchery-reared, from Crecy Lake, N.B.)
1140 (skin lesions caused by unidentified pseudomonad bacteria)
1187 (hypophysectomy effect on pituitary–interrenal axis)
A 30 (enzymic degradation of muscle glycogen & adenosine phosphate re quality)
57(F) (establishment & management of rearing in artificial ponds in Canadian Maritimes)

Trout, speckled (*see* Trout, brook)

Trout, steelhead (*Salmo gairdneri*) (*see also* Trout, rainbow)
J 24(5): 917 (fecundity in an Oregon river)
A 29 (weight changes during rigor while held in refrigerated sea water)

Trout-perch (*Percopsis omiscomaycus*)
A 14 (Great Bear Lake, N.W.T.)

Truscott, Beryl
J 24(1): 205 (1α-hydroxycorticosterone)
S 1114 (skate plasma testosterone)
1121 (steroid destruction by thin-layer chromatography)
1141 (*Raja* 1α-hydroxycorticosterone)
1167 (1α-hydroxycorticosterone biosynthesis)
1168 (1α-hydroxycorticosterone synthesis in vitro)

Trussell, Paul Chandos
J 24(2): 261 (marine-borer attack on wooden surfaces)

Tsuyuki, Hiroshi
J 24(2): 299 (Catostomidae electropherograms)
(6): 1269 (lamprey electropherograms)
(9): 1945 (*Sebastodes reedi* in NE Pac.)
S 1146 (insect oxidase–peroxidase system)

Tubiash, Haskell Solomon
J 24(6): 1413 (freeze-drying shellfish for solids)

Tullibee (*Coregonus artedii*) (cisco)
J 24(6): 1219 (oil yield & composition on reduction)
(6): 1291 (composition & nutritive value of meal)
S 1189 (oil fatty acids composition)
A 14 (Great Bear Lake, N.W.T.)

Tully, John Patrick
A 52 (weather of the sea)

Tumor
J 24(3): 679 (on freshwater mussel foot)
(9): 2007 (on snake prickleback snout)

Tuna, bluefin (*Thunnus thynnus*)
J 24(9): 1991 (transatlantic migrations of young)
A 43 (1965 Canadian ICNAF studies)
67 (description, distribution, behaviour, life history, fishery)

Tuna, yellowfin (*Thunnus albacares*)
J 24(3): 683 (feed of, in Barbados waters)

Tunas (*see also* Albacore)
B 160 (brine-spray freezing at sea)

Turbot (Atlantic) (*see* Halibut, Greenland)

Turbot (Pacific) (*see* Flounder, arrowtooth)

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Umbra limi (*see* Mudminnow, central)

Unio pictorum; *U. tumidus* (freshwater pelecypods)
J 24(5): 1165 (shell-weight re age in British waters)

Unloading
A 34 (fish from vessels by pumping)

Urchin, heart (*Brisaster latifrons*) (*B. townsendi*)
J 24(6): 1377 (speciation status)
(6): 1385 (off Oregon)

Urechinus loveni (*see* Sea urchins)

Urinary tract (*see also* Excreta)
J 24(2): 447 (anatomy, in trouts)

Urophysis chuss (*see* Hake, squirrel)

Ursin, Erik
J 24(11): 2355 (mathematical model of fish growth)

Ursus arctos (*see* Bear, polar)

Uthe, John Frederick
J 24(2): 299 (Catostomidae electropherograms)
(6): 1269 (lamprey electropherograms)

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Vaisey, Florence Marion
J 24(1): 9 (whitefish preservation with radiation)

Vallentyne, John Reuben Way
J 24(11): 2473 (simplified lake model)

Vancouver Island, B.C. (*see also* names of individual localities)
J 24(11): 2207 (oceanography off W coast)

Velsen, Frank Peter John
J 24(5): 1173 (insecticide effect on coho)

Venus mercenaria (*see* Quahaug, bay)

Vertebrae
J 24(4): 849 (incorporation of antibiotic for marking salmons)

Victoria Island, Canadian Arctic
A 75 (1965 limnology & fish study of Keyhole Lake)

Vinciguerria lucetia (*see* Lightfish)

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Vitamin B group
J 24(6): 1291 (in freshwater fish meals)

Vladykov, Vadim Dmitrovich
J 24(5): 1067 (terminology of lamprey teeth)

Volsella demissa (*see* Mussel, ribbed)

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W

Wainio, Allan Arthur
J 24(12): 2539 (lamprey parasitism of trout)

Walden, Cecil Craig
J 24(2): 261 (marine-borer attack on wooden surfaces)

Waldichuck, Michael
S 1120 (currents in coastal pollution studies)
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Walleye (*Stizostedion vitreum vitreum*) (yellow pickerel)
J 24(5): 927 (limnetic larvae in N Wisconsin lakes)
(11): 2229 (hypoxanthine in muscle of iced)
B 158 (in economics of N.W.T. commercial fisheries)
A 14 (re Great Lake Bear, N.W.T., sport fishing)

Walrus, Atlantic (*Odobenus rosmarus rosmarus*)
J 24(12): 2631 (Nfld. records)
S 1190 (skulls as evidence of presence on Sable Is., N.S.)

Walsh, Brenda
J 24(6): 1299 (guanotrophy in Rostherne Mere)

Warren, Peter James
J 24(3): 569 (feeding & migration patterns of pink shrimp)

Washington State
J 24(3): 629 (surf smelt populations heterogeneity)
(12): 2515 (Puget Sound starry flounder & sand sole stomach contents)

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J 24(2): 243 (of sockeye salmon flesh re sexual maturity & starvation)
(8): 1693 (of pickle-salted vs. brine-salted Atlantic cod)

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J 24(8): 1827 (effect of aliasing on oceanographic studies at)
(10): 2201 (line fishing results at)
(11): 2207 (annual changes in halocline at)
S 1137 (oceanography re salmon distribution)

Weber, Douglas Duane
J 24(4): 849 (marking Pac. salmon with tetracycline antibiotics)

Weight (*see also* Length–weight ratio; Size)
J 24(5): 1165 (as criterion of growth, particularly molluscan shell-weight re age)
(7): 1531 (vs. fecundity, Atlantic cod)
(11): 2355, 2414, 2417 (mathematics of losses in fasting fishes)
B 160 (changes in fish held in refrigerated sea water)
161 (round weights of goldeye; shrinkage)
A 12(F), 65 (gains & losses in Atlantic cod fillets immersed in tap water or brines)
29 (changes in fish passing through rigor while held in refrigerated sea water)

Wellings, Sefton Robert
J 24(9): 2007 (neurofibroma in *Lumpenus sagitta*)

Werner, Arthur Eugene
J 24(10): 2137 (kraft mill effluent in B.C. harbour)
S 1154 (bottom sediment gases sampler)
1157 (hydrogen sulfide oxidation kinetics apparatus)

Westrheim, Sigurd Jergen
J 24(6): 1187 (research trawl catches at sea)
(9): 1945 (*Sebastodes reedi* in NE Pac.)

Whale, blue (*Sibbaldus musculus*) (*Balaenoptera musculus*)
CAG 9 (NW Atl. populations, catches)
S 1190 (on Sable Is., N.S.)

Whale, Cuvier's beaked (*Ziphius cavirostris*)
J 24(12): 2503 (description of one stranded in N California)

Whale, fin (*Balaenoptera physalus*)
CAG 9 (NW Atl. populations, catches; description)
S 1111 (oil fatty acids re zooplankton feed fatty acids)
A 75 (Canadian Arctic studies, 1965)

Whale, humpback (*Megaptera novaeangliae*)
CAG 9 (NW Atl. populations)

Whale, killer (*Orcinus rectipinna*)
S 1115 (unusual group behaviour)

Whale, pilot (*Globicephala melaena*)
J 24(11): 2481 (wintering in Nfld. inshore waters)
S 1190 (on Sable Is., N.S.)

Whale, right (*Eubalaena glacialis*)
CAG 9 (NW Atl. populations)

Whale, sei (*Balaenoptera borealis*)
CAG 9 (NW Atl. populations, catches)

Whale, sperm (*Physeter catodon*)
CAG 9 (NW Atl. populations)
S 1190 (on Sable Is., N.S.)

Whale, white (*Delphinapterus leucas*)
A 75 (aerial census, Hudson Bay, 1965)

Whitefish, lake (*Coregonus clupeaformis*)
J 24(1): 9 (preservation by gamma radiation)
(9): 1911 (as parasite host, Nfld.)
(11): 2229 (hypoxanthine formation in iced muscle)
B 158 (physical & economic organization of N.W.T. fisheries)
A 14 (Great Bear Lake, N.W.T.)

Whitefish, round (*Prosopium cylindraceum*)
A 14 (Great Bear Lake, N.W.T.)

Wickett, William Percy
J 24(3): 581 (Ekman transport & zooplankton concentrations)
(6): 1421 (earthworms eaten by coho salmon)
CNG 80 (B.C. herring)

Wilder, Donald George
B 147(F) (lobster storage & shipment)
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A 4(F) (lobster fishery potential)
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J 24(5): 1017 (& nearby lakes: profundal benthic fauna)

Wisconsin
J 24(5): 927 (limnetic larval fish in N lakes)

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Withler, Frederick Curtis
J 24(7): 1573 (sockeye & pink ova & sperm fertility)

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J 24(1): 207 (description of eggs off N.S.)
A 43 (in Canadian ICNAF area)

Wolffish, Bering (*Anarhichas orientalis*)
A 75 (third specimen known from central Canadian Arctic)

Wood, Albert Lewis
J 24(7): 1461 (freeze-drying of Atlantic cod steaks)

Wood borers
J 24(2): 261 (estimating attack of *Bankia* & *Limnoria*)

Woodland, Gladstone Bruce
A 3 (FRB Annual Review)
56 (Atlantic salmon high seas tagging)
68 (career of FRB scientist)

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J 24(10): 2189 (primary productivity)

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A 40 (same as S 1159 above)

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J 24(10): 2195 (in unusual sockeye salmon skin pigmentation)

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J 24(10): 2011 (cutthroat trout homing & orientation)

Yew, Japanese (*Taxus cuspidata*)
J 24(11): 2497 (insect moult-hormone activity of extract from branches)

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J 24(2): 249 (equilibrium, per recruitment; computerized)
(12): 2527 (maximum sustained, re exploitation of multiple stocks)

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Zalembius rosaceus (*see* Seaperch, pink)

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Zebrafish (*Brachydanio rerio*)
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J 24(6): 1253 (zebrafish age re resistance to sulphate)

Ziphius cavirostris (*see* Whale, Cuvier's beaked)

Zoarces viviparus (*see* Eelpout)

Zooplankton (*see also* Feed; Krill; Plankton)
J 24(3): 555 (particularly calanoid copepods, Tanquary Fjord, Ellesmere Is.)
(3): 581 (concentration in NE Pac. re Ekman water mass transport)
(10): 2053 (micro, in California Current euphotic zone)
S 1155, 1172 (measuring grazing by electronic particle size enumerator)

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LISTS OF PUBLICATIONS

JOURNAL OF THE FISHERIES RESEARCH BOARD OF CANADA

(A complete list of the contents for the 1967 Volume 24 is included at the back of this issue for binding purposes.)

BULLETINS OF THE FISHERIES RESEARCH BOARD OF CANADA

156. CREAN, P. B. Physical oceanography of Dixon Entrance, British Columbia. 66 p.

157. RUTHERFORD, J. B., D. G. WILDER, AND H. C. FRICK. An economic appraisal of the Canadian lobster fishery. 126 p.

158. SINCLAIR, SOL, S. TRACHTENBERG, AND M. L. BECKFORD. Physical and economic organization of the fisheries of the District of Mackenzie, Northwest Territories. 70 p.

159. CARROTHERS, P. J. G. Automatic underwater photographic equipment for fisheries research. 34 p.

160. ROACH, S. W., H. L. A. TARR, N. TOMLINSON, AND J. S. M. HARRISON. Chilling and freezing salmon and tuna in refrigerated sea water. 40 p.

161. KENNEDY, W. A., AND W. M. SPRULES. Goldeye in Canada. 45 p.

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147. MCLEESE, D. W., AND D. G. WILDER. Le homard: entreposage et expédition. 75 p. [English edition published in 1964.]

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137. MANSFIELD, A. W. Seals of arctic and eastern Canada. 35 p. (Second edition, revised.)

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148. BELL, GORDON R. A guide to the properties, characteristics, and uses of some general anaesthetics for fish. 9 p. (Second edition, revised.)

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68. CLEMENS, W. A., AND G. V. WILBY. Fishes of the Pacific coast of Canada. 443 p. [Reprinted without revision.]

131. MEDCOF, J. C. Oyster farming in the Maritimes. 158 p. [Reprinted without revision.]

Arctic Biological Station, Ste. Anne de Bellevue, Que.

9. SERGEANT, D. E. Populations of large whale species in the western North Atlantic with special reference to the fin whale. 30 p. [1966.]

Halifax Laboratory, Halifax, N.S.

28. JANGAARD, P. M. The care and treatment of seal pelts. 2 p. [1966]

29. JANGAARD, P. M. Fish meal plants in eastern Canada. 5 p.

30. KAMRA, S. K. A report to the fishing industry on the problem of discolored flesh in gillnet turbot (Greenland halibut). 3 p.

31. JANGAARD, P. M. Frozen storage of whole lobsters. 2 p.

Biological Station, Nanaimo, B.C.

75. QUAYLE, D. B. Paralytic shellfish poisoning — safe shellfish. 9 p. [1966]

76. HERITAGE, G. D., AND T. H. BUTLER. Shrimp exploration in Hecate Strait and Queen Charlotte Sound, June to August 1966. 39 p.

77. OUTRAM, D. N. Herring spawn abundance in British Columbia 1966. 17 p. [1966]

78. KETCHEN, K. S. A review of the trawl fishery for Pacific cod with a forecast for 1967. 22 p.

79. KETCHEN, K. S. Recent developments in the domestic and foreign fisheries for groundfish in the northeastern Pacific. 13 p.

80. TAYLOR, F. H. C., AND W. P. WICKETT. Recent changes in abundance of British Columbia herring, and future propects. 17 p.

81. BOURNE, NEIL. A new method for digging butter clams. 9 p.

82. THOMSON, J. ARTHUR. Results of exploratory fishing for groundfish in Hecate Strait in 1966. 34 p.

83. OUTRAM, D. N. Herring spawn production in British Columbia in 1967. 8 p.

Biological Station, Nanaimo, B.C.
(Statistical Series)

25. BILTON, H. T., E. A. R. BALL, AND D. W. JENKINSON. Age, size and sex composition of British Columbia sockeye salmon catches from 1912 to 1963. 4 p. + 163 tables.

26. [Not yet published.]

27. [Listed and indexed in 1966 FRB Annual Index and List of Publications.]

28. FORRESTER, C. R. Trawl production by Canadian and United States vessels from grounds adjacent to British Columbia during the years 1954 to 1965, inclusive. 26 p. + 12 app. tables.

Vancouver Laboratory, Vancouver, B.C.

37. CLAGGETT, F. G. The preservation of summer herring aboard the fishing vessel. 15 p. [1966.]

Biological Station, St. Andrews, N.B.

51. DRINNAN, R. E., AND J. P. PARKINSON. Progress in Canadian oyster hatchery development. 4 p.

ANNUAL REPORT

Annual Report Fisheries Research Board of Canada 1965. 36 p. (combined English and French).

Annual Report Fisheries Research Board of Canada 1966. 26 p. (combined English and French).

STUDIES OF THE
FISHERIES RESEARCH BOARD OF CANADA

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